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THE BRITISH JOURNAL OF METALS


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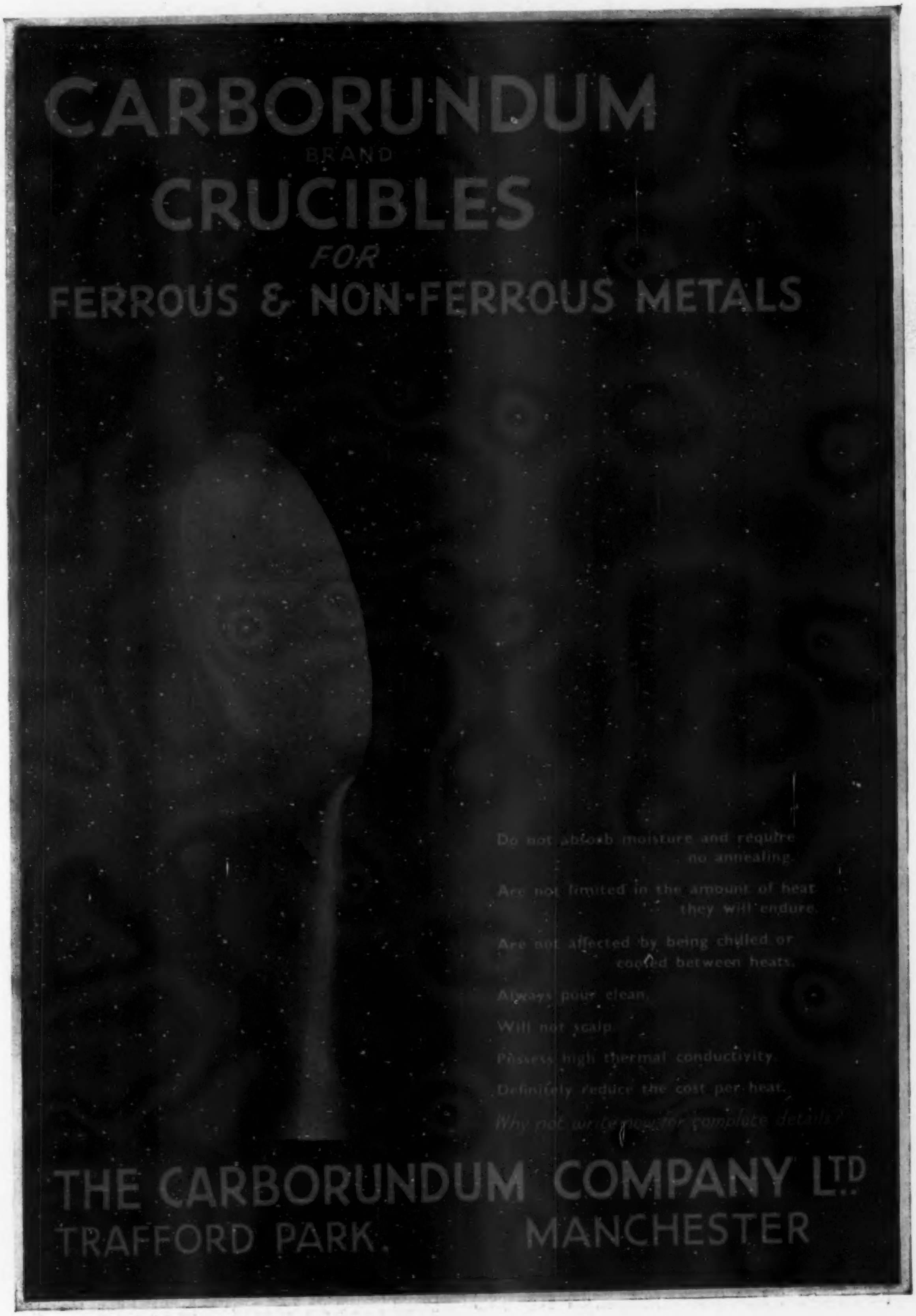
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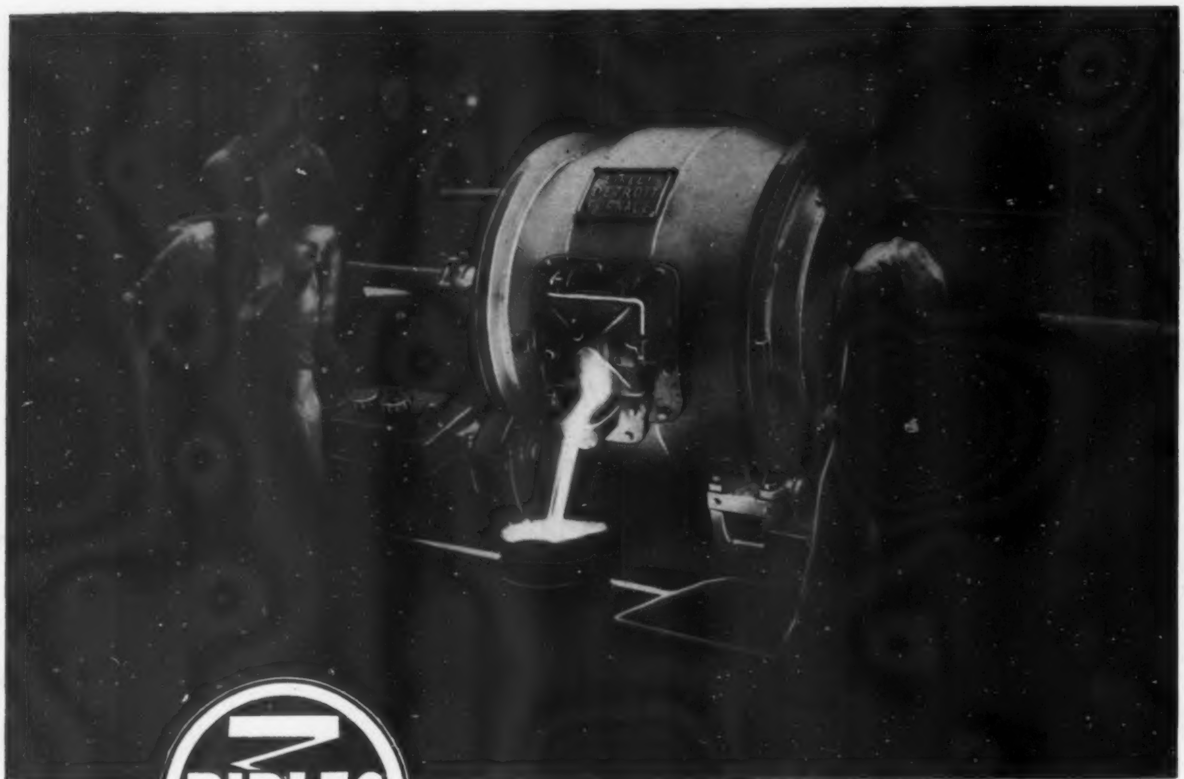


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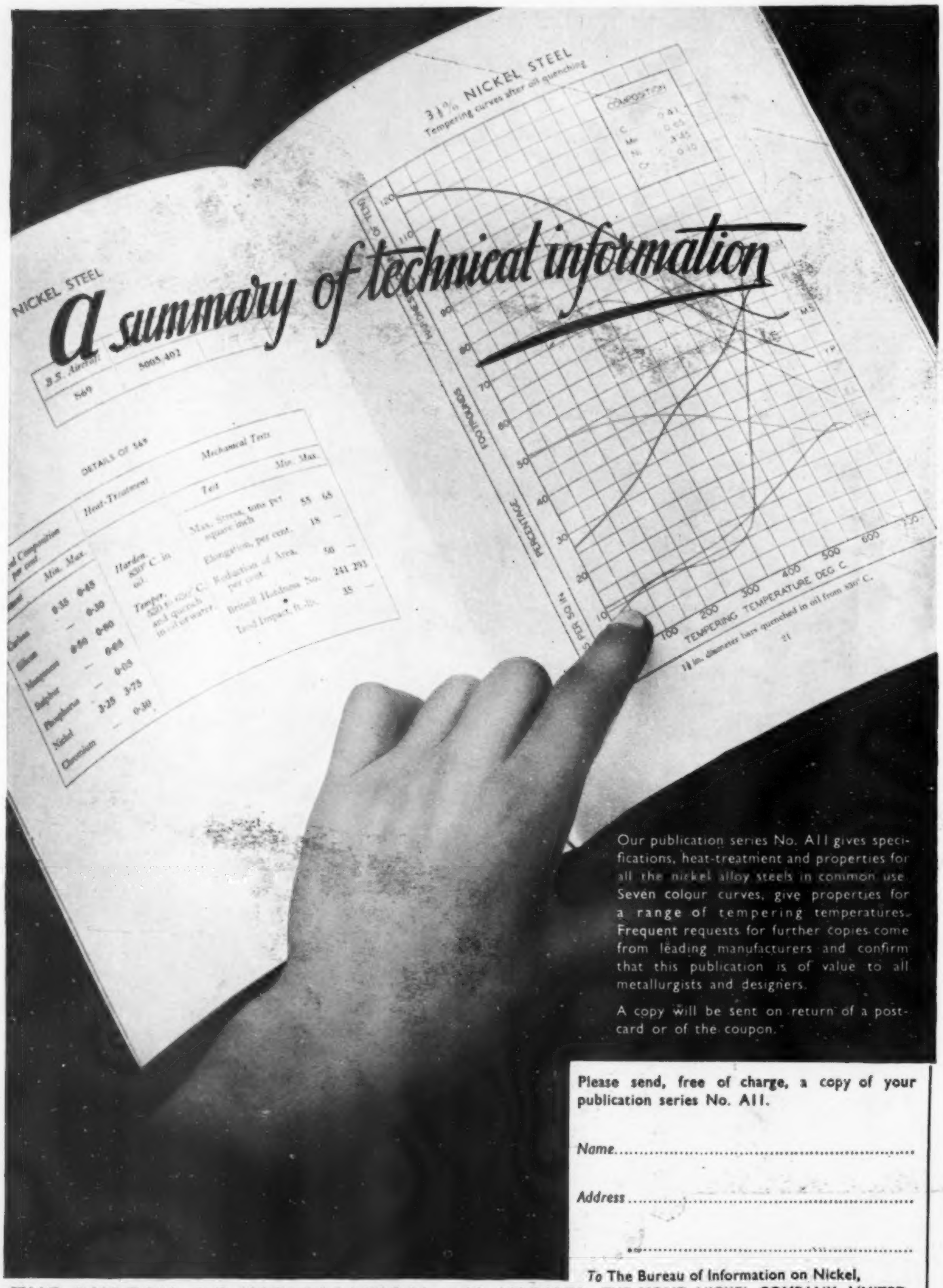

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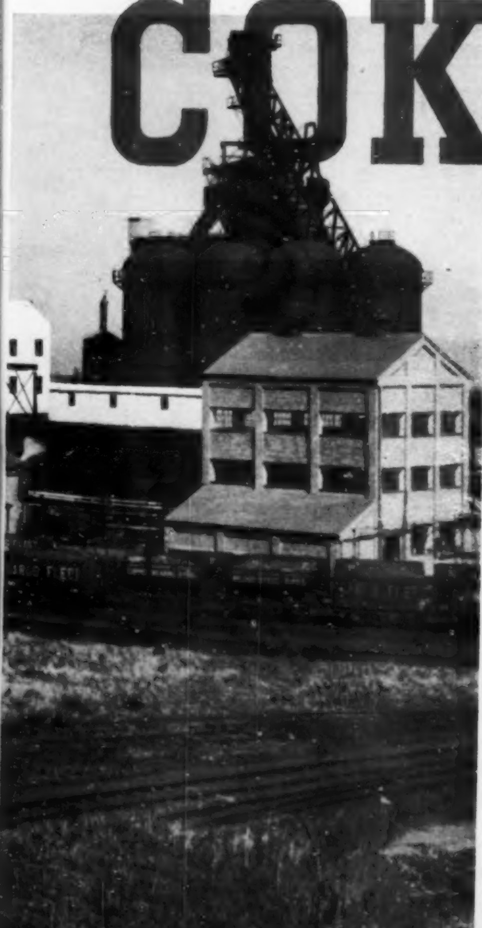


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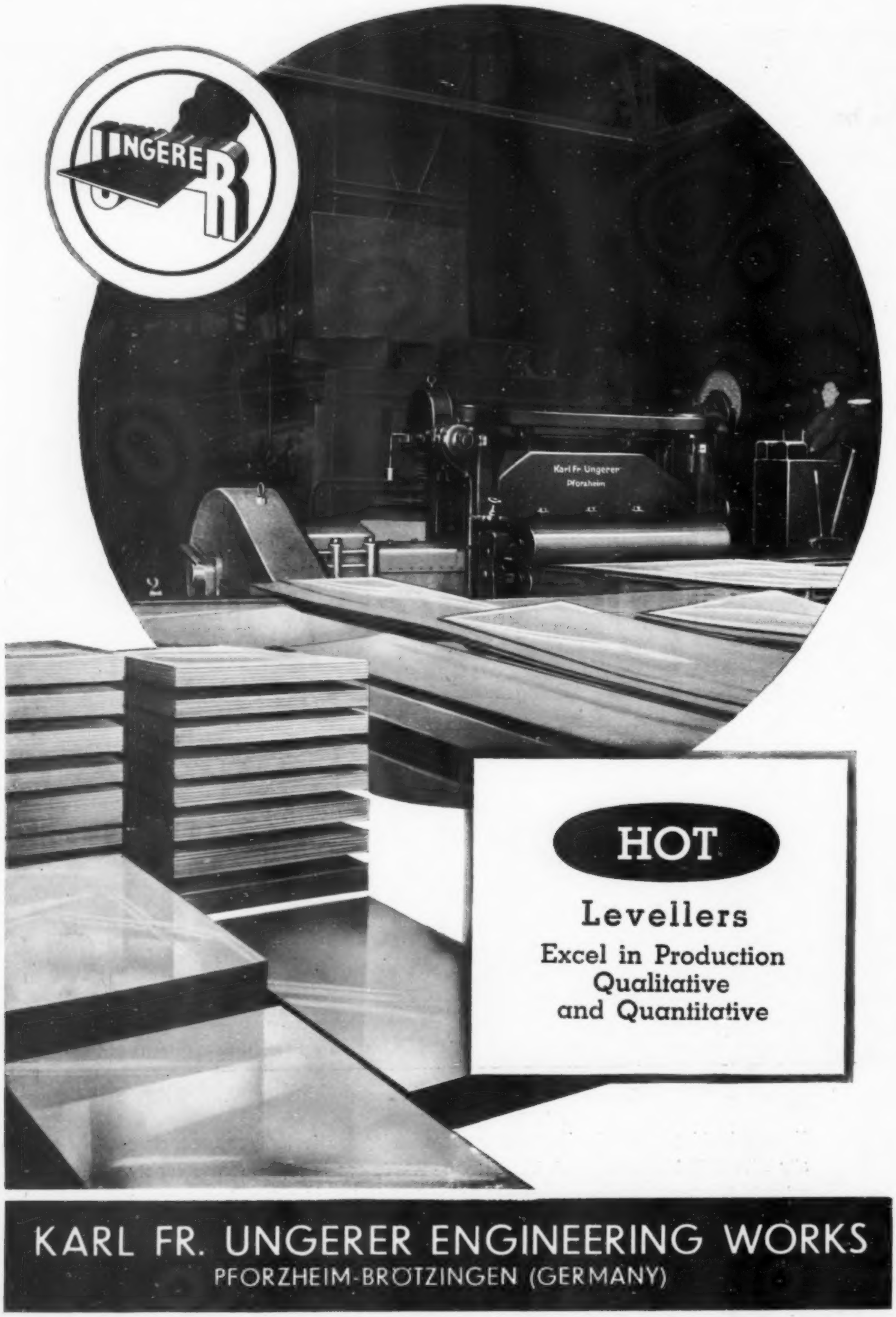
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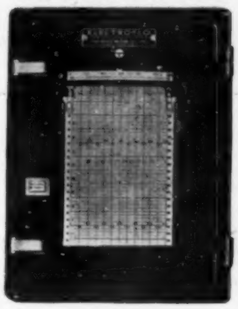

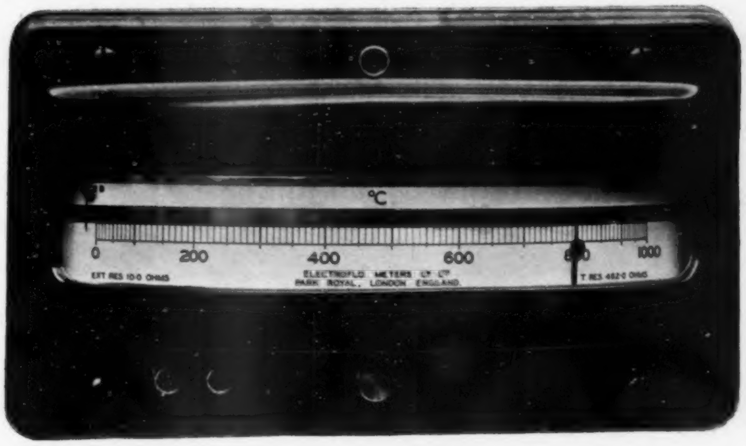

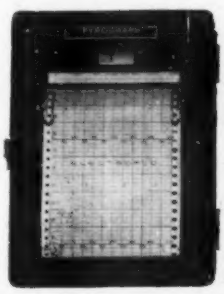

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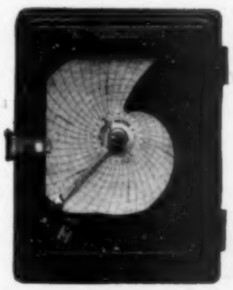

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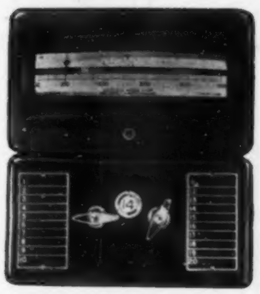

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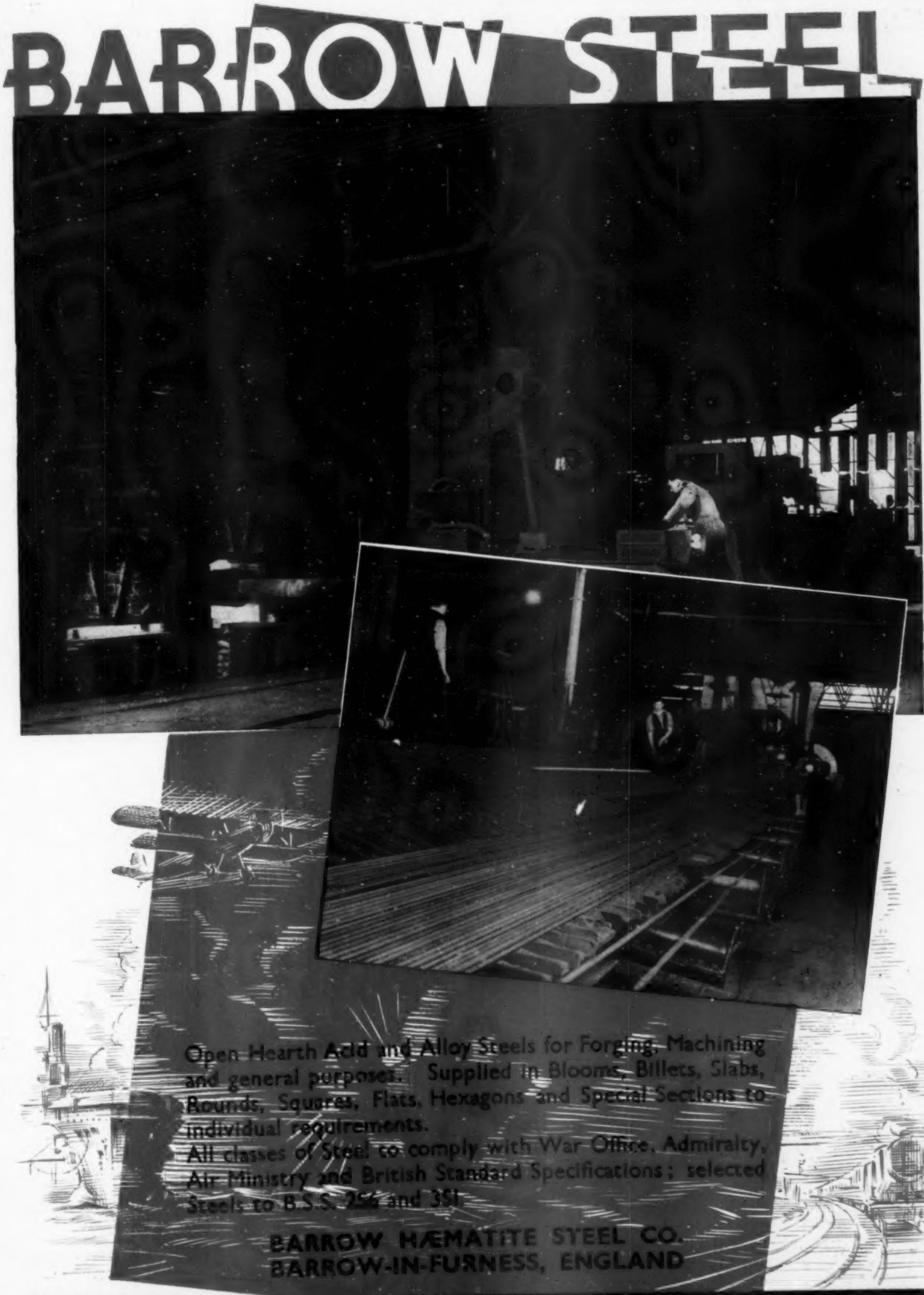
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METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER.)

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METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

OCTOBER, 1937. VOL. XVI, No. 96.

New Solutions of Old Problems

The Follsain Processes and Metals to Resist Oxidation, Sulphurous Gases, the Attack of Certain Corrosive Metals and other Media, and Abrasion.

With the cost of metals and alloys steadily rising many materials which have been developed to solve well-known engineering problems have become more costly, and this article describes some developments by Follsain Metals, Ltd., by which metals and alloys, capable of meeting many severe service conditions, are produced at moderate cost without sacrifice to the serviceability of the product.

IN recent years the services imposed upon iron and steel by the demands of the designer and engineer have been so exacting, particularly in regard to parts of structures exposed to high temperatures and destructive gases, to abrasion, and to the corrosive action of molten metals, sea-water and other liquids, that usefully long life has only been secured by alloying them with nickel, chromium, aluminium, tungsten, molybdenum, etc. The proper compounding of iron and steel into suitable alloys has proved of great value in extending the life of parts subjected to severe service conditions, but the use of these alloys frequently imposes a limit to the expansion of some industries whose products are expected to give long life under adverse conditions, because of the relatively high initial cost of suitable alloy irons or steels, and efforts are continually being made to reduce the cost without sacrifice to the serviceability of the product.

Considerable success has resulted from investigations in this direction, and a number of processes have been in commercial operation for some years. Of these particular mention may be made of developments by Follsain Metals, Ltd. This firm, after long experiment and research, has perfected and patented a number of processes and methods of manufacture by which alloys capable of meeting many severe service conditions are produced at moderate cost, and with remarkable regularity. During the past two or three years these metals have been tested under normal working conditions in a great variety of industries, and the results have so exceeded expectations that the developments of this firm are now regarded as important contributions to the solution of many well-known problems.

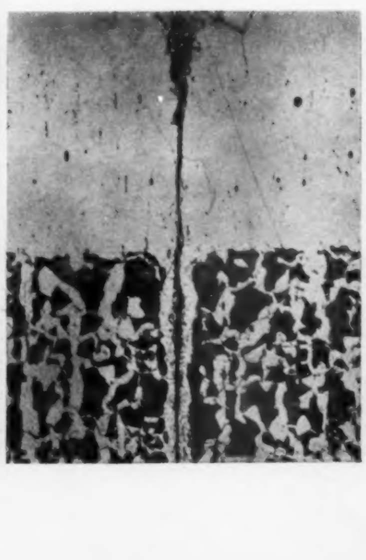
The fields in which these developments are proving advantageous concern those industries employing high temperatures, operations and processes that involve exceptional abrasion, or articles exposed to certain forms of corrosion, and brief information regarding these processes and metals may be usefully given here. The developments come under three main categories: one is a special cementation or, more accurately, an endosmotic process by which the surface of mild steel, cast steel and certain iron castings are impregnated to a depth varying with the time and temperature of treatment; another is a heat-treated cast metal produced specially to provide high resistance to wear; while the third development is a new and patented process by means of which Follsain Metals, Ltd., produce ferrous alloys possessing high resistance to oxidation and relatively high strength at temperatures up to 1,175° C., and also certain cast stainless steels.

Impregnation Process

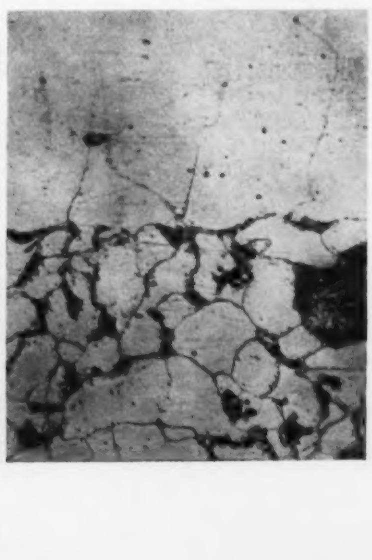
In principle the process of impregnating the surface of metals is not new, but considerable work in this field has

The Penetral H.T. treatment applied to a mild-steel tube. × 38.

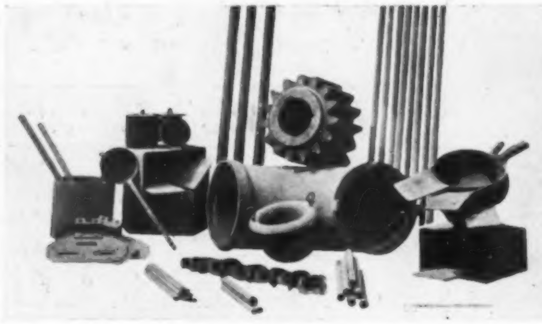
Showing how the formation of the penetration alloy proceeds in the walls of metal surrounding a slag inclusion.



Junction between penetration alloy and the base metal. × 370.



Section of a standard superheater mild-steel tube after treatment, showing the penetration alloy on both the inside and outside of the metal.



Miscellaneous products treated by the penetration process.

been carried out by Follsain Metals, Ltd., and a special cementation process has been developed which provides, by penetrating from the surface, a considerable depth of resistant alloy. The articles to be treated are packed in powder in a suitable container and heated in ovens of special design. A valuable feature of the process is that it can be applied within very wide limits to fabricated articles.

The effect of processing any article, made in a suitable metal, by this method is that the outer section of the metal, by impregnation and diffusion of some of the components of the treatment powder, is converted to the required depth into a new ferrous alloy which contains aluminium, silicon and chromium, and which resists oxidation and/or the attack of sulphurous gases, or a carburising atmosphere in conditions where temperature of the metal does not exceed 1,000/1,050° C. It is noteworthy that this process is being successfully applied to mild steel, carbon and most low-alloy steels, and to low-carbon cast irons, or, in general, to ferrous metals in which the carbon content is low.

This treatment is experiencing a rapidly increasing demand in a wide range of industries. It is being used for the treatment of carburising boxes, cyanide pots, pyrometer sheaths, superheater and airheater tubes, heat exchangers, burner and furnace parts, including sootblowers. It has been demonstrated to be of outstanding value wherever ferrous metals, either forged, rolled or cast, are exposed to oxidising conditions or sulphurous fumes at high temperatures.

Two definite limitations to the use of articles treated should be observed—viz., there should be no direct impingement of a keen flame of the blow-pipe type, and the temperature of the metal should not be allowed to exceed 1,000/1,030° C. Thus, for instance, pyrometer sheaths which have been treated by this process should not be used for temperatures in excess of 1,000° C. Airheater tubes, on the other hand, may safely be used in cases where the heating gases attain temperatures up to 1,400° C. This is due to the relative cooling effect of the air passing through the tubes, which prevents the metal of the tube rising above the danger-point.

Metallic airheaters or recuperators treated by this process applied to melting furnaces have been working for the past three or four years with complete satisfaction. These recuperator tubes are placed in the direct flow of the waste furnace gases, which may rise to a temperature of 1,400° C., while the temperature of the air leaving the heaters is usually about 700° C., and in some cases as high as 850° C. Results indicate that the initial cost of such installations has been more than justified since the upkeep cost has been reduced to negligible proportions, while the high-thermal efficiency maintained provides a higher and more constant air temperature than is usually obtained.

An interesting application of the process is encountered in the oil-cracking industry, where mild-steel, molybdenum, carbon, and nickel-chrome steel tubes are in general use according to conditions of service. With increase in the severity of the service conditions the cost of suitable alloy steel tubes rises rapidly. The treatment leaves the physical properties of the metal unaffected, so that in cases where creep or other stresses are in excess of the capacity of a mild carbon steel an alloy with the necessary physical properties can be substituted, and the protective properties of the impregnated surface layer are not impaired.

A High-Grade Case-Hardening Process

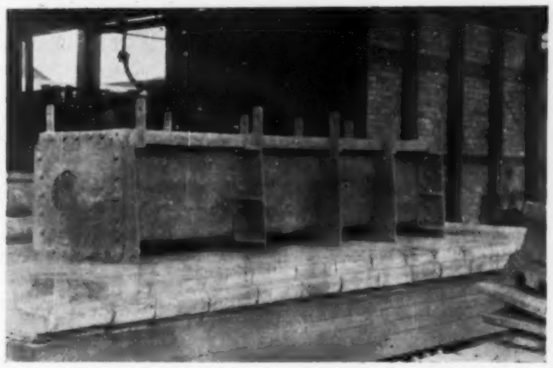
Another process, the first stage of which is carried out on somewhat similar lines to the impregnation process, has been developed which may be described as a high-grade case-hardening process. In this process both the time and temperature of treatment and the composition of the packing powder are different, and the treated articles are subsequently quenched. Although suitable for a wide range of ferrous metals, it is not usually applicable to cast irons.

A very hard layer is obtained by this process—Vickers diamond hardness, 850 to 1,000,—and the hardened section remains completely bonded into the soft core, without any tendency towards flaking and cracking. Tests made at the National Physical Laboratory indicate that this process results in a product with a resistance to abrasion superior by about 22% to that of good case-hardening. The process is especially advantageous when maximum hardness is required, combined with freedom from flaking, and at the same time a ductile core. It is suitable for the treatment of larger parts than are usually dealt with by case-hardening. A number of heavy steel pinions have been treated and have given very satisfactory service.

Another variation of the impregnation process previously described is a process originally evolved to provide an acid-resisting surface. At the moment the commercial application of this process is limited, but it has been found especially successful in connection with galvanising machine parts, and also for pyrometer tubes for use with molten tin and zinc. A considerable amount of research work remains to be done to develop the application of the process, but there is a large potential field for a treatment that produces an acid-resisting surface on a comparatively low-priced material.

Rollers for pulverising coal in the abrasion-resisting metal.

Crowns and discs for International Pulveriser Co. machines made in the abrasion resisting metal.



Heat-treatment box. The body made of mild steel plates—the supporting casting made of heat-resisting steel. This box works at 1150° C., and the bridles have outlasted three sets of plates (the fourth is shown in the illustration), and the heat-resisting steel is unscathed.

Abrasion Resisting Alloy

Next to corrosion probably the greatest destruction of metals results from abrasive wear in industry as a whole, and any low cost metal, possessing suitable properties, which successfully resists wear of this character is a useful contribution to metallurgy, and an advantage to the engineer confronted with abrasion problems. To meet the increasing demand for greater resistance to abrasive wear this Company has developed a machinable alloy cast iron which is particularly suitable for crushing and grinding machinery. Its outstanding property depends upon the combination of its analysis, and the heat-treatment to which it is subjected in the course of manufacture.

It is well known that manganese steel depends for its abrasion-resisting qualities upon the effect of work-hardening, and unless its surface is given the heavy blows necessary to work-harden the austenitic structure its resisting qualities are relatively poor; this characteristic is, however, fully developed in the manufacture of the alloy cast iron referred to.

This alloy is very fluid when molten, and can be cast into intricate shapes; it machines well, but, as might be expected with a material primarily intended to resist abrasive wear, the operation requires modern and heavy-type machine tools. When suitably heat-treated the alloy has a tensile strength of 30—35 tons per sq. in., and its Brinell hardness is about 250. It is particularly suitable for crusher and pulveriser rollers, liners and chute plates, and gives remarkable service in the presence of abrasive material such as coke, sand, grit, crushed slag, crushed granite, etc.

Heat-Resisting Alloys

For many purposes in which high temperatures are involved, the manufacturer of parts must take into account all the working conditions. Not only is it necessary to use materials which resist oxidation, but they must be capable of carrying the required load at elevated temperatures, and to resist the varying effects of furnace gases. Many alloys have been developed which, at the higher temperatures, combine the three required properties—resistance to oxidation, strength and permanence of form. The most important of these are the ferrous alloys containing various proportions of nickel, chromium and molybdenum; but difficulties are frequently encountered in their manufacture, especially in the cast form.

To provide a means for solving this problem, Follsain Metals, Ltd., have carried out much research as a result of which a method of melting has been developed by which alloys of this type can be cast at a temperature only slightly above the melting-point, and in a free-flowing condition suitable for the most intricate shapes. This method, which is patented, is applicable to the most complex alloys, which may be cast without risk of porosity or blow-holes. These features, together with remarkable freedom from non-metallic inclusions, are incorporated in a heat-resisting alloy manufactured by this Company. It is essentially a nickel-chromium-iron alloy which, in service, is shown to have remarkable resistance to oxidation, sulphurous and other furnace gases, and corrosion, and in addition it possesses good mechanical properties at temperatures ranging up to 1,175° C.

The suitability of this alloy for parts exposed to severe service at high temperatures has been fully demonstrated under both laboratory and commercial conditions. It is especially suitable for furnace parts, case-hardening boxes, pyrometer tubes, heat-treatment trays, etc. It is more expensive than mild steel or cast iron, but its life is usually at least 20 times longer under similar conditions of service, and the weight of parts made in the alloy can be substantially reduced without sacrifice of service.

The Follsain Works

The plant and equipment at the Wycliffe Works, Lutterworth, where these processes are operated and metals manufactured, are of a modern character. The actual production of castings for treatment or in the special alloys is carried out, and the castings are finish-machined, if desirable, in the Company's machine shop. The treatment recuperator and other tubes by the impregnation process is carried out in a special pulversied fuel-fired furnace installed by Messrs. Gibbons Bros., Ltd. It is 50 ft. long, and is so arranged that its length can be adjusted to accommodate tubes of shorter length, with a view to economical heating of the furnace. This furnace is equipped with a Kennedy pulverisr, and the burners can be independently operated. Smaller parts to be treated are processed in smaller furnaces of the semi-gas-producer type. The temperature at which the treatment is carried out is in the range of 1,100/1,150° C., and the time of the process is dependent upon the depth of impregnation desired.

A special type of oil-fired furnace is installed for the type of case-hardening previously mentioned. This process is somewhat similar to the impregnation process adopted to provide resistance to oxidation, but the packing compound and temperature vary to give the degree of hardness desired while retaining a strong ductile core. The alloy cast iron developed for wear resistance is melted in a Sesci or Stein and Atkinson rotary furnace, and the heat-treatment of the subsequent castings is carried out in pulverised fuel-fired furnaces, while the nickel-chromium, heat-resisting alloy is manufactured in an oil-fuel fired Morgan crucible tilting furnace.

All the manufacturing operations are carefully controlled by an efficient staff of a well-equipped laboratory. Frequent tests are made not only of a routine character, but with a view to determining the best means of combating adverse conditions in service so that modifications can be made to the general practice to meet special service conditions.

The writer takes this opportunity of thanking the Follsain Metals, Ltd., for permission to visit their Wycliffe Works, and the chief metallurgist, Mr. Binley, for much helpful information.

Materials and their Testing

Technical Discussion Organised by the Manchester Association of Engineers.

The first technical discussion under the auspices of the newly formed Joint Committee of Technical Institutions on Materials and Their Testing will be held at the College of Technology, Manchester, on October 29, 1937, at 2-30 p.m. The meeting will be organised by the Manchester Association of Engineers, which is one of the co-operating Institutions, and will take the form of a discussion on Notched Bar Impact Testing. The following papers will be presented:

"The Physical Meaning of Impact Tests," by Professor R. V. Southwell, M.A., F.R.S., M.I.Mech.E., F.R.Ae.S.

"Some Aspects of the Notched Bar Tests" (in two sections—viz., a brief review of past experiments in this country, and an experimental exemplification of several features of the test), by L. W. Schuster, M.A., M.I.Mech.E., M.I.E.E.

"The Development and Present Position of Continental Research on the Notched Bar Impact Test," by Dr.-Ing. Max Moser.

Advance copies of the papers may be obtained at a charge of 2s. 6d. per set of three. Tickets of admission and copies of the papers may be obtained from Mr. T. Makemson, Secretary, Manchester Association of Engineers, St. John's Street Chambers, Deansgate, Manchester, 3.

Canadian Iron and Steel Production in August

The production of pig iron in Canada in August totalled 74,578 long tons, as against 38,570 long tons in August, 1936; whilst the output during the first eight months of the year was 578,258 tons, as compared with 413,893 tons in the corresponding period last year. Ferro-alloy production totalled 9,913 tons in August, as compared with 9,290 tons in August, 1936. The output for this year to date aggregated 47,816 tons, as compared with 51,060 tons during the corresponding months last year.

The production of steel ingots and castings totalled, in August, 126,695 long tons, as compared with 122,968 long tons in July, 1937, and 80,164 tons in August, 1936. The cumulative production during the first eight months of the year amounted to 962,840 tons, as against 727,657 tons for the corresponding period in 1936.

Gold Mining in Canada

One of the principal events at the joint convention of the Canadian Institute of Mining and Metallurgy and the American Institute of Mining and Metallurgical Engineers, at Vancouver, B.C., was the display of the new six-reel film, "Unlocking Canada's Treasure Trove." The film opens with a prologue depicting scenes from the early history of prospecting and mining for gold in Canada. This is followed by an interesting and informative description of present-day gold-mining operations, all of the mining scenes having been taken first hand. While the picture is a composite one, made up from "shots" taken at half a dozen of Ontario's principal gold producers, it portrays general practice throughout Canada in the extracting of gold.

Shifts of miners are seen changing, the operation of the hoists and ore skips are described, the drilling undergronnd, the blasting of the ore, sampling, ore transportation and subsequent handling before reaching the mill are strikingly shown. These scenes are followed by the seemingly endless process through which the ore must be put before the gold is finally recovered. Three of the principal processes—the all-cyanide, flotation cyanide, and amalgamation—used in gold recovery are shown through every stage until the gold reached the mill refinery. The refining of the gold to crude bullion and the despatch of the finished product to the Royal Mint occupies the concluding scenes of the film.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Nov. 5. Thomas Hawksley Lecture: "The Gas Engineer and After," by F. W. Lanchester, LL.D., F.R.S.

INSTITUTE OF METALS.

Birmingham Section.

Nov. 4. "Die-casting," by A. C. Street, Ph.D., B.Sc.

London Section.

Nov. 11. "The Training and Employment of Metallurgists," by R. S. Hulton, D.Sc., M.A.

North-East Coast Section.

Nov. 9. Joint Meeting with the Society of Chemical Industry and Institute of Chemistry.

Sheffield Section.

Nov. 9. "Powder Metallurgy," by J. C. Chaston, B.Sc., A.R.S.M.

Swansea Section.

Nov. 9. "Qualitative Analysis of Minute Inorganic Samples," by Miss I. H. Hadfield.

MANCHESTER METALLURGICAL SOCIETY.

Oct. 20. "Metals Used in Railway Work," by H. O'Neill, D.Sc.

Nov. 3. Joint Meeting with the Institute of Metals.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Nov. 5. Andrew Laing Lecture: "Development of Hull Form of Merchant Vessels," by Dr. G. S. Baker, O.B.E.

INSTITUTE OF BRITISH FOUNDRYMEN.

Birmingham Branch.

Oct. 22-23. Joint Meeting with the London Branch in Birmingham.

Nov. 5. Presentation of Report of Costing Sub-Committee of the Technical Committee. "Recommendations Concerning the Establishment of Costs in a Grey-Iron Foundry," by V. Delport.

East Midlands Branch.

Oct. 23. "Patternmaking for Production Moulding," by S. A. Horton, at Loughborough.

Lincolnshire Section.

Nov. 1. "Recent Developments in Foundry Machinery," by V. C. Faulkner, F.R.S.A.

Lancashire Branch.

Nov. 6. "Cupola Practice in a Textile Engineering Works," by J. Jackson.

London Branch.

Oct. 22-23. Joint Meeting with the Birmingham Branch in Birmingham.

Nov. 3. "Trends of Continental Steel Foundry Practice," by P. Fassotte.

East Anglian Section.

Oct. 21. Visit to Works of Crane, Ltd., Ipswich.
Presidential Address by L. J. Tibbenham, A.M.I.Mech.E.
"Some Problems Involving the Accuracy of Machine-moulded Castings," by A. H. Squire.

Middlesbrough Branch.

Oct. 22. "Foundry Products through the Microscope," by E. B. Ellis.

Newcastle-on-Tyne Branch.

Oct. 30. "Treatment of Iron Castings after Casting," by H. Herdman.

Scottish Branch.

Nov. 13. "Some Impressions of Modern Foundry Practice," by H. Lowe.
"The Relation of Moisture to Principal Properties of Moulding Sands," by J. Dearden, B.Sc.

Sheffield Branch.

Oct. 29. Joint Visit with the Lincoln Section to the Works of Messrs. Ruston and Hornsby, Ltd.

Wales and Monmouth Branch.

Nov. 6. "Moulding Castings for a Vertical Pump Motor," by T. W. Trayherne (at Cardiff).

West Riding of Yorkshire Branch.

Nov. 13. Works Visit to Messrs. J. Blakeborough and Sons, Ltd.

ROYAL AERONAUTICAL SOCIETY.

Students' Section.

Nov. 2. "Light Alloy Castings and Stampings for Aeronautical Purposes," by W. C. Devereux, F.R.Ae.S.

METALLURGIA
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The Motor Show

Some Significant Factors that Contribute to the Progress of the Motor Car

THE Thirty-first International Motor Exhibition, which this year is held at Earls Court, is now regarded as one of the events of the year. It has grown in popularity with each succeeding year and has contributed in some measure to the progress made in the manufacture of motor-cars. It has been the means of bringing together the products of British and foreign manufacturers in one common " shop window," and each manufacturer has tried to make his exhibits outstanding from the points of view of design, quality and/or price. Rapid strides were made in this respect in the early years of the show, when spectacular innovations were frequent, and were expected, and there were considerable differences between cars of comparative power and price ; to-day, however, design and construction are much more stabilised, and it is very unlikely for any one car, whatever its price, to become the " lion of the show."

Although there are few surprises at the show, it is one of London's chief attractions, and until October 23, the closing date, thousands of people will inspect the cars on view. It is, of course, of great importance to the motor-manufacturing industry and to the great number of other industries that supply its needs. This is the only opportunity provided in this country where potential buyers can make comparisons. And, to-day, these comparisons go beyond graceful lines or colouring that a car may have. With the rapid growth of motor-car users more people are now mechanically minded and are concerned with performance as well as comfort and service in addition to good lines.

During recent years manufacturers have concentrated on increasing the brake-horse-power, but almost invariably this is being accomplished by higher engine speeds which affect the design and construction of the engine. The greater power at higher engine speeds demand higher compression ratios, lighter reciprocating parts, improved valve mechanism, and it makes greater demands on the materials of which the various parts are composed. Thus, at the great motor-manufacturing works in Coventry, Birmingham, Luton, London, Dagenham, and elsewhere, much valuable work has been and is being done, not only in introducing refinements to the design of power units, nor in establishing a new or modified manufacturing technique, but in determining the most suitable metals or alloys which will give longer service under the more severe conditions resulting from higher engine speeds.

Choice of Materials

The importance of the choice of materials for the engine and its details is recognised, and all the well-known motor-car manufacturers possess adequately staffed and equipped laboratories designed not only to carry out routine tests, but also to cary out investigations with a view to facilitating the selection of a material suitable for a particular service. In addition, however, much work has been carried out under the auspices of various technical societies, the main object of which has been to find out the most suitable materials which, when used in the manufacture of a car, will give the owner of that car at least a reasonable return in service on his investment. After all, the best recommendation is a trouble-free car, and it is the desire to produce such a car, rather than revolutionary developments, which causes intense rivalry among manufacturers. The term " trouble-free " is, of course, purely relative, and depends largely upon the materials used in the car's construction, and although this may be regarded as an economic factor, even the cheapest cars are necessarily constructed with a view to service that can reasonably be regarded as being long.

The use of higher compression ratios has brought its own problems, suitable fuels are available, but the increase in power that has resulted has also increased the need to dissipate an almost proportionate increase in waste heat. Possibly, this is one of the reasons why complaints of excess heat in enclosed models have been heard. One manufacturer has increased the cooling efficiency by providing larger water capacity in the system, and considerable care has been devoted to design of bulkheads insulating the engine compartment from the body interior. But considerable success has been achieved by using metals for the cylinder heads which have a relatively high thermal conductivity.

The choice of materials for the cylinder heads has been given special consideration during the last two or three years with the object of increasing engine power and efficiency. Aluminium alloys have proved valuable in this respect, while aluminium bronze has also been used for the purpose. Considerable interest is attached to a more recent development involving the use of copper heads. As is well-known, the thermal conductivity of copper is much greater than any of the base metals and its efficiency for dissipating heat will be appreciated. Experiments have shown that, using copper cylinder heads, and with suitable modifications to the engine, such as adjustment of the compression ratio, the performance of an engine can be improved by 20 per cent. The difficulties of casting copper, unless the design of the heads can be modified, retards the commercial adoption of copper for this purpose, but this is likely to be overcome in the near future.

Another problem associated with higher engine power, through higher compression ratios, is that concerning the valves. In this instance the dissipation of the heat is much more difficult, and to provide for adequate service special heat-resisting steels are necessary. Valve springs, too, have been given attention as a likely cause of failure from increased engine speeds. The increased wear encountered between the cylinder and the piston rings has been the cause of much study and, although the factors that provide resistance to wear under conditions that operate in the cylinders continue to be elusive, much has been done to increase service in this respect.

But the work done in the laboratory to make the modern motor-car trouble free is not confined to the engine, the materials employed for each component and the treatment to which it is submitted come under survey. With the number of components in the average car running into thousands the task of selecting the most suitable material for each is no light one, yet reasonable care must be experienced in the choice, and due regard must be paid to modifications in the speed and power of the engine.

Increased power influences the fatigue properties of materials and makes modifications in the choice of materials

necessary, so that greater resistance to fatigue can be provided. Gradually, for instance, the carbon steels are being displaced by low-alloy steels, and a range is available from which tensile strengths of 35 to over 100 tons per sq. in. are obtained. These two factors, fatigue and wear-resisting properties, are probably the most important to the motor-car user who naturally desires a trouble-free car, and it is natural that he should concern himself with the materials which are likely to provide this condition. It is not surprising, therefore, that many users are not only mechanically minded, but also take more than a passing interest in the constitution of what he regards as the key components.

This trend is being appreciated by British motor-car manufacturers and on the stands of the various exhibitors at Earls Court are experts who are able to give considerable metallurgical information regarding the composition of important components and, in fact, many manufacturers make a feature of emphasising the quality of components and making various claims for the particular material used. There is, therefore, some truth in the statement that no industry has given more attention to metallurgical considerations, and, in a large measure, it is due to this policy that British motor-car manufacturers have made such rapid progress in home and foreign markets. There is much yet to be done before all cars can be regarded as trouble-free, but steady, persistent study of the problems encountered will lead to further progress for future shows.

New Aluminium-Base Bearing Alloys

Considerable attention has been given recently to the development of aluminium base alloys for bearings. There are, of course, several factors which must be considered in the choice of a bearing metal, but the essential characteristics of a suitable alloy must embrace its running properties, load carrying properties, working temperature, wear resistance, action on the material of which the shaft is composed, coefficient of thermal expansion and fatigue impact strength. These characteristics appear to be very satisfactorily supplied by a new aluminium base alloy known as Alva 36, according to Vaders.*

The Alva series of alloys are aluminium-lead-antimony alloys with additions of copper, manganese, iron, etc. and have been developed by the Vereinigte deutsche Metallwerks A.G. It is claimed that the alloys are equally suitable for the manufacture of bushings as well as for the lining of bearings. They can therefore be used as substitutes for copper-bearing alloys as well as for white metal. This is due to the fact that the alloys can be given sufficient mechanical strength, while at the same time preserving the easy working properties of tin-bearing alloys. It is noteworthy that these alloys, as distinct from the tin alloys, can be readily hot-worked, which enables them to be obtained in various semi-finished forms.

Investigations to determine the bearing temperatures against specific bearing load at different running speeds indicate that Alva 36 alloy is definitely superior to both tin base and copper base alloys and will operate satisfactorily at temperatures and under loads which will lead to rapid destruction of both these other types of bearings. After the tests the ordinary, unhardened steel shaft showed no wear and the bearing itself had a smooth surface and the amount of wear was negligible. Compression tests on the alloy showed that it possessed excellent ductility, a cylinder being compressed cold to 68% deformation without any cracks forming. The corresponding figures for copper, tin and lead bearing alloys tested under similar conditions showing 55, 33 and 56% deformation respectively. The coefficient of expansion of this new alloy is $21 \cdot 8$ times 10^{-6}.

Messrs. Edgar Allen and Co. Ltd. announce the appointment of Mr. W. H. Greaves as assistant representative for Scotland. Mr. Greaves will work in conjunction with the Company's chief representative in Scotland, Mr. A. MacPhail.

* E. Vaders. *Z. Metalk*, 1937, 29. 5. p. 155.

Verein deutscher Eisenhüttenleute

Recent General Meeting in Düsseldorf

In his introductory speech at the opening of the general meeting in Düsseldorf of the Verein deutscher Eisenhüttenleute, Dr. Otto Petersen said that the most important event was the union of the technical-scientific associations with the NS-Bund deutscher Technik. He went on to make a number of well-deserved acknowledgements and spoke highly of the founding of the steelworks association, through whose activities young student engineers had been sent on various tours.

In the foreground of the work of the Verein, he continued, is the consideration of ore, German ore, and the possibility of smelting it in the best possible manner. In regard to the importance of smelting, Dr. Petersen stated that in Germany, as in England, much serious study had been made, mentioning that the acid process in England, indicating what he called the so-called Corby ore, had already been brought to a successful stage.

He also made reference to the developments at Corby works in burdening the blast furnaces in such a manner as to result in a considerable saving in fuel with the production of a hotter metal, reference to which is made elsewhere in this issue.

Dr. Petersen spoke in highly appreciative terms of the work of Sir Harold Carpenter, F.R.S., and of Mr. James Henderson. The Verein deutscher Eisenhüttenleute conferred signal honours on these two prominent members of the Iron and Steel Institute; the Carl Lueg Gold Medal was awarded to Sir Harold (the immediate Past-President of the Institute, and Professor of Metallurgy at the Royal School of Mines) and Mr. Henderson, who is a Director of the United Steel Companies Ltd., and Deputy Chairman of the Appleby-Frodingham Steel Co. Ltd., was elected an Honorary Member of the Verein.

The present Verein was founded in 1881 since when, only sixteen Honorary Members have been elected, and the tribute to Mr. Henderson is all the greater when it is realized that only once before has an Englishman been accorded this honour.

Relationships between the Iron and Steel Institutes and the Verein deutscher Eisenhüttenleute have always been cordial. The Institute held its Autumn (1936) meeting in Düsseldorf at the warm invitation of the Verein—acting on behalf of the German Iron and Steel Industries—and it will be recalled that a delegation of Members of the Verein took part in the Institute's Annual General Meeting in London this May. On that occasion Dr. Fritz Springorum (President of the Verein and Chairman of the Hoesch-Köln Neuessen A.-G. für Bergbau und Hüttenbetrieb) and Dr. Ernst Poensgen (a Member of the Council of the Verein and President of the Vereinigte Stahlwerke) were elected Honorary Vice-Presidents, and Dr. Otto Petersen, the Director of the Verein, was elected an Honorary Member of the Institute.

British Foundry School

The Governors of the British Foundry School view with some concern the fall in the number of students during the second session compared with the thirteen registered for the first session. It is recognised that the number of students in the school at any time is likely to be small, but it is impossible to expect the Board of Education, which provides such generous grant aid, to continue unless the number of students really shows that there is an industrial demand. It is urged that all those responsible for the conduct of foundry operations, directly or indirectly, should consider whether the school can aid them in building up a suitable personnel.

Communications should be addressed to British Foundry School, c/o, Central Technical College, Suffolk Street, Birmingham, 1.

High-Duty Brasses and Bronzes available to the Engineer

Their Properties and Applications

By F. HUDSON

The demand for alloys to withstand severe service conditions has become increasingly insistent during recent years, and in this and succeeding articles, the author discusses developments in brasses and bronzes to supply this demand. In this article attention is directed to various classes of high-duty brasses, and it is suggested that future development will centre round those alloys capable of being hardened by heat-treatment.

MUCH has been heard during the past few years about alloy steels and high-duty cast irons for severe service, and it is pardonable to ask: "What about high-duty brasses and bronzes? Are developments in non-ferrous metallurgy lagging behind?" The answer to this question is most decidedly in the negative. To-day there is available to the engineer a fairly wide range of cast and fabricated non-ferrous metals eligible for this service and possibly possessing latent physical properties beyond even the most comprehensive ideas.

In one direction, particularly that of casting production, some of these alloys are much superior to iron or steel, due to the facility with which they may be poured into intricate shapes of remarkably fine finish in conjunction with a uniform measure of strength, corrosion resistance and solidity. With quite normal technique tensile strengths between 30 and 50 tons per sq. in. can be readily obtained, and up to 70 tons in special instances, as for example, in the recently-developed beryllium bronzes. At the present time, however, this latter material is not a practical proposition in view of its cost being about 16 times greater than the more common alloys on the market, and accordingly any subsequent remarks will be directed more towards those metals capable of direct practical application than to those in a lesser state of development.

Many of the alloys within this range of maximum stress mentioned also exhibit remarkably good impact and fatigue values. For example, aluminium bronzes, in the forged condition, are available and capable of giving an Izod impact value around 65 ft.-lb. associated with a maximum stress of just over 33·0 tons per sq. in., and having a fatigue resistance favourably comparable with the stainless steels.

One particular advantage of the non-ferrous metals is the high ratio of strength in the cast state, in comparison to that after forging, with the result that in most cases castings can be produced having physical properties little short of those obtained by hot-working. In many instances this is of considerable economic value. Improvements have also been observed in the hardness of high-duty brasses and bronzes, and it is now quite common to obtain material between 200 and 300 Brinell.

These developments have been brought about by metallurgical research and the consequent extension of our knowledge relative to the effect of additions of such metals as nickel, aluminium, manganese and silicon. If one takes for example a standard aluminium bronze containing 10% aluminium, 90% copper and quench it in water from 850° C., certain optimum maximum strength and hardness values will be obtained in conjunction with relatively low impact and elongation. By reheating at temperatures up to 650° C., the strength and hardness values decrease, and greater toughness and ductility is obtained. In other words, this alloy can be hardened and tempered in a manner similar to steel. Upon the addition of 2·0 to 7·0% nickel the optimum maximum stress and hardness values are not reached with the initial quench, but are obtained after the tempering operation when temper-hardening or ageing has been said to occur.

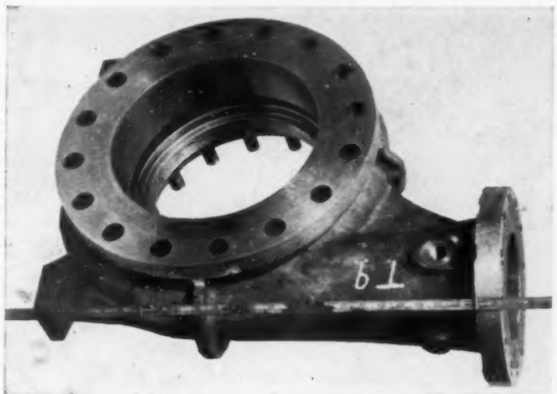
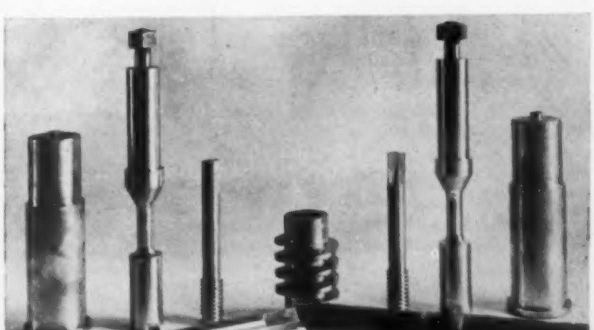


Fig. 1.—Typical casting application of high-duty brasses. (Feed pump casing.)

Invariably the physical properties obtained from alloys susceptible to temper-hardening are considerably greater than those which do not exhibit this phenomenon and this factor has proved of considerable value in the development of non-ferrous metals for high-duty work. The true mechanism of the reaction which takes place is by no means clear, but sufficient evidence has been collected to indicate that the presence of definite amounts of nickel and aluminium, or nickel, tin and manganese, are critical factors. In the case of the latter combination a longer and more accurate thermal treatment is possibly required to develop the best results. With some casting alloys it is even possible, by control of the cooling rate, to arrange for some measure of temper-hardening to occur during founding, with beneficial results, although, in most instances, the reaction is never quite complete when conducted in this manner, and consequently not associated with the maximum properties obtainable.

Fig. 2.—Group of high duty brass forgings.



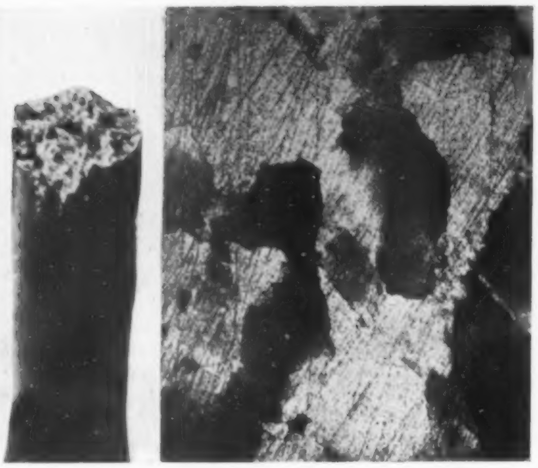


Fig. 3.—Beta structure, high tensile strength but susceptible to fatigue. Note "woody" structure. × 50.

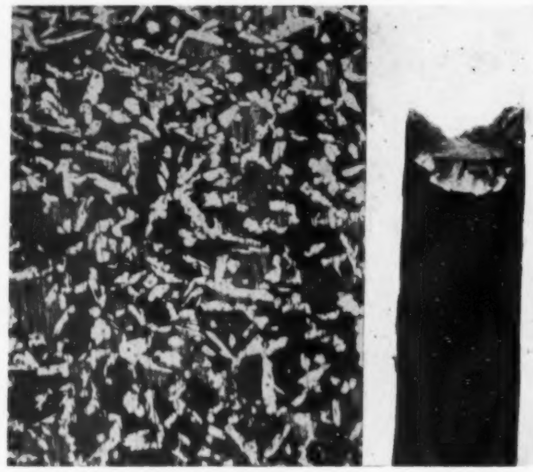


Fig. 4.—Alpha-plus-beta structure which should be aimed for in the production of high-duty brasses. × 50.

High-Duty Brasses

The high-duty brasses as used in engineering embrace a wide variety of cast and wrought products ranging from very large marine propellers down to smaller castings, such as locomotive axleboxes. In the forged, extruded or rolled condition this class of material is extensively used for pump rods, valve spindles, operating mechanism, etc. A typical casting application is illustrated in Fig. 1, whilst Fig. 2 shows a group of forged products.

In considering any particular service requirement, there is one very important point, common to all the alloys in this group, which must be kept in mind—the relation of structure to fatigue failure. All the high-duty brasses within the full beta or beta borderline range of compositions, and having a microstructure and tensile fracture as shown in Fig. 3, are notoriously susceptible to premature failure by fatigue or corrosion fatigue. This trouble is likely to be most pronounced in parts subjected to stress reversals, such as is experienced in valve spindles and pump rods. Accordingly, it is a safe rule to employ, as far as possible, brasses having a composition such as will give an alpha-plus-beta structure in the finished article as represented in Fig. 4, notwithstanding that such a structure is accompanied by a lower tensile strength.

Instances are known where premature failure of high-duty brasses has occurred, and the trouble has only been accentuated by attempts to increase the tensile strength alone. Such an example is shown in Fig. 5. These are two sections cut from forged valve spindles, the threads of specimen B, which exhibited a beta structure, having stripped after only a few months' service, although the tensile strength was around 40 tons per sq. in. In the case of A, indefinite service has been obtained by reducing the maximum stress value down to 30 tons per sq. in., but with a consequent increase in fatigue resistance coincident with the presence of an alpha-plus-beta microstructure. It will also be noted that the grain size in this latter specimen is much finer than in the former, and this has been brought about by careful control of methods of alloying in conjunction with thermal treatment during melting, casting and forging.

Large grain size is obviously most undesirable in high-duty brasses, and compositions producing a beta structure seem to be most susceptible to this trouble. The production of fine-grained brasses is best assured by standardisation on a composition which will yield an alpha or alpha-plus-beta structure in the finished article. The presence of iron and possibly nickel are of considerable value in this question of grain refinement. Obviously, high-duty alloys are not necessarily those with the highest tensile strength, and the selection of any particular alloy must of necessity depend upon service conditions, keeping in mind the main fundamental facts already stated.

The so-called "manganese and aluminium bronzes" are not bronzes in the true sense of the term, and in reality should be considered along with the alloys in this group, and in view of the fact that the aluminium bronzes are possibly of latest interest, it is proposed to comment on these first.

Aluminium Bronze

This material essentially embraces those alloys of copper containing up to 10·0% aluminium. In the majority of cases additions of other metals such as iron (up to 5·0%), manganese (up to 1·0%), and nickel (up to 7·0%) are made, as it has been found that these impart superior physical properties.

From the engineering point of view, the alloys are at present more suitable for the production of forged articles than for sand castings, as they are difficult to handle in the foundry, although investigations are being actively conducted, at the present time, in order to obtain improvements in this latter direction. They are, however, used quite successfully for the production of die castings. The aluminium bronzes as a whole are much superior to the zinc-containing high-duty brasses, so far as corrosion and fatigue resistance are concerned.

They are not nearly so subject to failures like dezincification, and give good results under strenuous service conditions, even in the presence of corrosive agents, although some evidence has lately been obtained that the elimination of iron from the composition is desirable for the best results in this direction. Furthermore, it is important that the aluminium content should not exceed 9·8%, as there is some tendency, under certain conditions of cooling, for a brittle phase to arise in these alloys when this limit is exceeded.

The straight aluminium-copper alloys containing above 7·5% aluminium are susceptible to heat-treatment, and can be hardened and tempered similarly to steel, but much greater latitude can be obtained in this direction by the addition of nickel, when the phenomena of temper-hardening is brought about over a wide range of nickel-aluminium ratios. There are several commercial alloys available in this latter group, as shown in Table I, possessing remarkable physical properties, and these are likely to be extended as further research work is completed. They are particularly valuable for service at temperatures up to 460° C., and over as they do not show a large drop in physical properties, and consequently are useful for consideration in problems dealing with superheated steam and high-temperature gases. Furthermore, in this latter application they do not scale readily.

At one time aluminium bronze was used quite extensively for inlet- and exhaust-valve inserts for aero and other internal-combustion engines, but with the advent of higher cylinder compressions with consequent increase in com-

bustion temperature, together with the use of doped fuels, operating conditions have become too severe so far as the exhaust insert is concerned, and the practice now is to substitute stellite for this service. Bronze, however, is still used in many cases for the inlet-valve insert and for applications such as this the temper-hardening alloys containing nickel possess obvious advantages. Some of the alloys are marketed under trade names such as Crotorite, Superston bronze, etc.

High-speed machining is somewhat of a difficulty with all the aluminium bronzes, as in this respect it behaves more like steel, and the usual high rake angles of tools used in non-ferrous machining practice are unsuitable. It is advisable to employ even lower rake angles than for steel in heavy, rough turning operations.

The aluminium bronzes can be satisfactorily fusion welded by the use of a flux containing borofluorides and silicofluorides, and also brazed relatively easy with the lower melting-point solders, but ordinary soft soldering is not a practical proposition, unless the surface is copper-plated. The alloys have been used in industry for miscellaneous die castings such as small gearwheels, electrical machinery sections (brush holders, contact segments, etc.), roller-bearing cages, automobile parts, and other cast and fabricated articles such as valve spindles and operating rods, pump rods, worm-wheels, valve inserts, marine fittings, beater bars for paper pulp machinery, crane hooks, etc.

Manganese Bronze

Those alloys having a copper-zinc base with the addition of other metals such as iron, manganese, aluminium, nickel and tin, constitute a distinct group of high-duty brasses Possibly the material known as " manganese bronze " is one of the oldest and best-known in this class. As a high-duty brass it has in the past been used extensively for cast and fabricated sections such as large marine propellers, water turbine runners, axle boxes, ship fittings, valve spindles and pump rods, propeller shafts, bridge bearing plates, rollers, springs, non-corrodible ladders, etc.

The alloys containing zinc are much easier to handle in the foundry than the aluminium bronzes previously mentioned, but are not nearly so resistant to corrosion

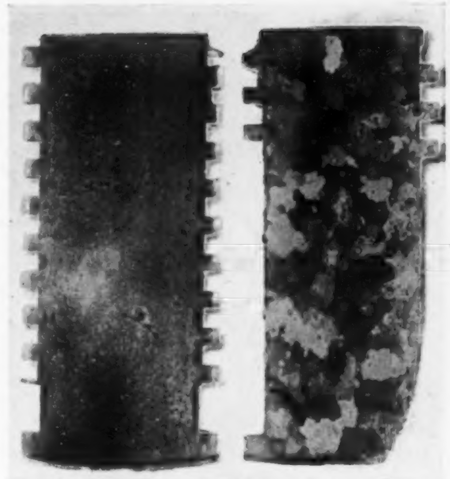


Fig. 5.—Effect of grain size and structure on the fatigue failure of valve spindles.

or fatigue. The usual run of manganese bronze compositions are liable to corrosive attack by dezincification under even mild corrosive influences, and numerous failures have occurred in this direction under high-duty service conditions. The trouble can be overcome to some extent by the addition of up to 1·0% tin, but the improvement obtained is still not comparable to that exhibited by the aluminium bronzes.

Most of the alloys in this group are also susceptible to season cracking tendencies particularly when extruded or drawn and reeled. This danger can be overcome by an annealing treatment, but very often this limits the physical properties available for high-duty service, and much better results can be obtained by taking advantage of the temper-hardening properties imparted by the addition of nickel and aluminium. The heat-treatment in this latter case whilst improving the physical properties also releases internal stresses due to cold work, and thereby removes all tendencies to season cracking. High-duty brasses are now available having these properties, such as Kunial brass, and they permit easier and more reliable production

TABLE I.

APPLICATIONS AND MECHANICAL PROPERTIES OF HIGH-DUTY BRASSES (ALPHA, OR ALPHA-PLUS-BETA).

Material.	Composition. %.									Mechanical Properties.					Condition.	Typical Applications.
	Cu.	Zn.	Al.	Ni.	Fe.	Mn.	Sn.	Pb.	Be.	Yield. Tons per sq. in.	Max. stress. Tons per sq. in.	Elong. % on 2 in.	Izod impact. Ft.-lbs.	B.H.N		
Beryllium Copper*	97·8	—	—	—	—	—	—	—	2·2	19	28	14	—	109	Cast.	Springs for electrical work and instruments. Contact studs (wears well and prevents arc formation). A small percentage of nickel is sometimes added for grain refinement.
										42	53	1	—	400	Quenched 800° C. Aged 340°C.	
										44	46	7	—	190	Drawn.	
										62	86	2	6	365	Quenched 800° C. Aged 300° C.	
Aluminium Bronze	89·8	—	9·3	—	0·4	0·5	—	—	—	10	30	31	—	86	Cast.	Die castings. Worm wheels. Valve spindles and parts. Pump rods. Valve inserts and faces. Beater and refiner bars for paper mills. Impeller shafts Gun mountings. Fatigue and corrosion-resisting structures. Maintains good strength properties at temperatures up to 450° C.
										21	38	17	—	119	Forged.	
										21	39	11	—	143	Quenched 900° C. Reheated 500° C.	
	84·8	—	10·0	5·1	—	0·1	—	—	—	20	39	24	19	143	Forged.	
										19	37	37	25	125	Forged and annealed 900° C.	
										30	48	10	8	218	Forged. Quenched 850° C. Reheated 650° C.	
	89·7	—	5·0	2·0	3·0	0·3	—	—	—	16	33	34	67	130	Forged.	
Manganese Brass	57·2	41·0	0·3	—	0·7	0·8	—	—	—	15	32	31	28	129	Forged. (Castings give similar properties with possibly lower elongation and impact values.)	Marine propellers. Valve spindles. General castings and hydraulic fittings not subjected to severe corrosion.
Copper-Nickel-Aluminium Alloys and Brasses*	92·5	—	1·5	6·0	—	—	—	—	—	23	44	20	—	194	Rolled bar. Quenched 900° C. Reheated 600° C.	Springs and heat-treated articles made from sheet. Small cut gear wheels
	72·5	20·0	1·5	6·0	—	—	—	—	—	31	47	11	—	240	Cold-rolled strip. Reheated 500° C.	Intricate pressings, etc. Non-sparking tools, spanners.
	60·0	34·0	3·0	3·0	—	—	—	—	—	17	37	19	—	125	As cast.	High-tensile castings. Roller bushes.
										21	40	28	—	148	Forged bar.	
										28	46	18	—	272	Forged bar. Quenched 780° C. Reheated 450° C.	
Silicon Manganese* Bronze	95·5	—	—	—	—	1·0	—	—	Si 3·5	18	29	24	—	120	Forgings.	Chemical plant. Shovels for explosive manufacture. Good resistance to corrosion.
	91·5	2·0	—	—	2·0	0·5	—	—	Si 4·0	30	41	22	—	130	Extruded bar.	

* It should be noted that some of these alloys are covered by patents.

methods to be employed, particularly in the manufacture of articles in sheet or wire form. For example, the temper hardening properties allow springs to be shaped in the soft or semi-soft condition, and then given full elastic properties by suitable heat-treatment. Other obvious values are in the possibility of hardening small-toothed clock and instrument wheels, fabricated sheet articles, roller bushes, non-sparking tools, spanners, etc.

It is interesting to note that in connection with this last application hardness and strength values equal to steel can be obtained. In the case of the aluminium-nickel-bronzes and the aluminium-nickel-zinc brasses capable of temper-hardening it should be pointed out that the softest condition is obtained by the initial quenching treatment from around 800° C., as they cannot be annealed in the same way as ordinary brass by heating to around 600° C. The high-duty brasses are easily machined, and they can be readily soft-soldered, and in this direction are superior to the aluminium bronzes. Typical physical properties of the various alloys in this group are given in Table I.

Silicon-Manganese-Copper Alloys

In addition to the aluminium bronzes and high-duty brasses some mention should also be made of those alloys containing silicon and manganese with copper. In comparison with the previous alloys they do not enter the high-duty class, so far as castings are concerned, but fairly good mechanical properties are available in the forged or otherwise worked condition, as will be observed from Table I. The material known as Everdur is probably the oldest alloy on the market, and has been extensively used in the United States for some years, particularly for corrosion-resisting purposes. It also possesses exceptional properties at low temperatures, its strength and ductility both increasing with fall in temperature, and this fact has been recognised by the use of this alloy for applications at — 100° C. and below. For example, a ½-in. dia. drawn bar has a tensile strength around 34 tons per sq. in. with 5% elongation on 2 in. at 0° C., and equivalent values of 38 tons per sq. in. with just over 6% elongation at — 100° C., rising to 45 tons with 8% elongation at — 200° C. This alloy has been successfully used for applications such as battery-room drains and ducts, cable clips, filters, storage tanks, pumps, screens, valves, shovels for use in explosive manufacture, etc.

P–M–G metal is a further development in this class of alloy containing additions of iron and zinc as well as those metals already mentioned. In the forged state excellent properties are obtainable, but the properties of castings are below those obtained with the aluminium bronzes and high-duty brasses, although they are of particular value for their strength at high temperature in comparison to the cast gun-metals, and mention will be made of this later when considering the question of high-duty bronzes.

In the selection of high-duty brasses for severe service it is probably advisable to take into account yield point and impact value rather than maximum strength, and in view of what has been previously mentioned in regard to the importance of standardising on an alpha or alpha-plus-beta structure for general purposes, future development will undoubtedly centre around those alloys containing nickel and which are capable of being hardened by heat-treatment. In the case of compositions giving an all-beta structure the effect of nickel tends to reproduce the alpha constituent, and whilst there does not seem to be much difference in the maximum strength values of alloys with and without nickel, it is possible that the addition of this metal will very definitely result in improved properties being obtained so far as toughness and fatigue resistance are concerned.

(To be continued.)

Largest Ingot Ever Produced in this Country

NOT many years ago the production of a steel ingot weighing 100 tons was looked upon as somewhat of an achievement. The advances and changes in heavy engineering, and the demands of the engineer and designer in connection with some of the more recent schemes they have evolved, have had to be met by the steel-maker, with the result that in 1932 English Steel Corporation, Ltd., at their Vickers Works produced the largest ingot that had ever been made in the country—175 tons.

They have now gone a step further and produced a steel ingot of 230 tons in weight, approximately 25 ft. long by 10 ft. across corners. This ingot, which was made in a chilled mould, is the largest ever made in this country. The ingot, which will be made into large forgings in connection with the Government Defence Programme, will be brought to a forging temperature in a reheating furnace prior to forging under a 7,000-ton press, the largest forging press of its type in the world—i.e., to be operated by a high-pressure electro hydraulic pumping set. This press can comfortably deal with ingots of 300 tons in weight.

Placing gear over the head of 230-ton ingot in order to lift out of casting pit.

Charging the ingot into a reheating furnace at the Vickers Works.

Causes of Trouble in Heat-Treatment

By W. F. CHUBB

Many are familiar with the persistent trouble in the hardening shop caused by free cementite in the case of a carburised and hardened component. In this article the author suggests a remedy which experience has shown to be almost a complete cure.

PERHAPS the most persistent trouble met with in the hardening shop is that caused by free cementite in the case of the carburised and hardened component. There is little point in recalling the worries which result, such as flaking, cracking during hardening, and hair cracks developed during grinding operations, for these will be only too well known to all. It is the purpose of this article to suggest a remedy which experience has shown to be an almost complete cure.

Many remedies have from time to time been advanced, and it is now common practice to redissolve the free cementite, when known to be present in injurious amounts, by reheating the component to a temperature at least as high as its temperature of formation. In other words, it is believed that the only cure is that of reheating to the carburising temperature in order to remove that network of cementite which is the cause of all the trouble. This practice may lead to cracking if the quenching is done in water, but some hardeners adopt the remedy of making the first quench in oil. This may be for some components too slow to retain the iron carbide in solution, and the excess of carbide over the eutectoid percentage may be precipitated out of solution either wholly or in part. Under these circumstances, the old conditions favouring cracking of the case will be regenerated. It must be said, moreover, that this treatment renders the low carbon core of the work in an unsatisfactory condition, since if, for example, the case has been generated at a carburising temperature of 930°–950° C. it will be necessary to reheat to at least this temperature range to take the excess carbide into solution. Since the core of case-hardening mild steel requires a temperature no higher than 880°–900° C. for refining, it will be evident that this high-temperature retreatment, admirable as it can be in so far as the case of the article is concerned, can only result in a degree of overheating of the core which may be as much as 70° C. It is the author's experience that few case-hardening mild steels will successfully withstand any such severe overheating as this, and this is particularly true of some of the cheaper qualities available. The reasons for this will be evident to most practising metallurgists. A further disadvantage of this treatment is that during subsequent hardening of the carburised surface, usually undertaken at about 760° C., refining of the core does not occur, so that at the completion of its hardening treatment the steel is not in its best physical condition, and the mechanical properties suffer accordingly. This is evident in the fracture, as well as in the results of Izod impact tests taken with specimens machined from the core. It is, however, possible to rectify this matter completely by using the first reheating to 950° C. as a means only of redissolving the excess cementite, and then following with the usual double treatment at 900° and 760° C. The disadvantages of such a procedure are that liability of surface decarburisation is still further increased by the extra reheating involved, in addition to which there is always further danger of distortion.

Other treatments have been specified. One such treatment is that of Hanson and Hurst, which was designed for the complete removal of the carbide network as far as possible. The method advocated was that of annealing after carburising. To accomplish this, the boxes containing the carburised components are cooled very slowly in the furnace over a period of some hours, and the temperature is thereby lowered from the carburising temperature to one intermediate between the Ar_1 point and the temperature employed during the second quenching treatment for hardening the case. In practice, this treatment means that the component is held for several hours at a temperature a little in excess of Ac_1 and is still thus in an austenitic condition, and temperatures of 740° to 780° C. may be successfully employed for this purpose. The essential point is that the steel must not have reverted to its ferrite-pearlite structure by being allowed to cool to temperatures below Ar_1.

This treatment, which may be performed with every success if carried out properly, is based upon the fact that during furnace cooling from the carburising temperature the solubility of iron carbide in the austenite is lowered progressively, and thus the carbon content of the outer case is reduced, so that the presence of free cementite is almost entirely avoided. This can only occur if sufficient time be allowed for the necessary diffusion of carbide to be completed, and the time required adds materially to the length of the carburising operation.

An alternative process adopted by the author overcomes some of the objections which could be raised to this treatment. The aim of this alternative treatment is based upon spheroidising. In carrying out the process the pots containing the carburised components are cooled to a temperature below the carbon change point. This cooling process need not necessarily be a very slow one, as in the Hanson-Hurst treatment, and in fact the load may be withdrawn completely from the furnace. It is then placed in a second furnace, held at a temperature of 650° to 690° C., and is maintained at this temperature for a predetermined period, which depends upon the size of the component, the degree of over-carburising, and upon the results desired. The charge may be transferred direct from the carburising furnace to the soaking furnace, or it may be allowed to cool in air before charging into the second furnace. If the second course be adopted it is sufficient only to allow cooling to black heat before recharging into the soaking furnace. This treatment will break up the cementite network sufficiently to remove its harmful effects, and, of course, if the soaking treatment be long enough the network will disappear completely and be replaced by spheroidised cementite. This treatment also allows a certain measure of carbide diffusion to take place. Hence, after subsequent cooling in the ordinary way, the components will have a superficially carburised zone in which very little cementite occurs as a network and in which it can be made to exist more or less completely in the globular form. In the latter form the case can be hardened much more easily, and the components are very much less susceptible to cracking during cooling for hardening.

In this scheme the practical hardener will see the following advantages :—

(1) High carburising temperatures, which can be employed to speed up the operation, are less dangerous to the component.

(2) The effects of fluctuating carburising temperatures during carburising can be effectively removed during the soaking period.

(3) The carbon content of the carburised zone can be controlled to any desired limits to suit particular components by suitable choice of soaking times.

(4) Because the carbon content of the case can be controlled, the hardness of the finished article can be controlled also.

(5) Grinding risks are very considerably reduced, due to removal of the cementite network.

(6) The presence of free cementite in the hardened case in the spheroidised form adds materially to the frictional qualities of the surface.

I had thought to describe this treatment, for the purposes of this article, as a modification of the Hanson-Hurst suggestions, but since the principle of operation is essentially different, it cannot be so described. Indeed, it was worked out without reference to that process. It is only necessary to add that once the proper treatment has been decided for any particular component the process can be worked on a production basis with little or no interference to work being carried out simultaneously. The above treatment was, indeed, adopted for the carburising of camshafts, which, as is well known, are often difficult to harden without risk of flaking and cracking. Furthermore, in grinding the cams, hair cracks often appear, caused by the presence of cementite in network form. When reduced to this spheroidised condition no such conditions can arise, and, in fact, during extended use over a period of three years the author cannot remember even one failure arising from this treatment.

[The Editor welcomes contributions under the head "Causes of Trouble in Heat-Treatment. Such contributions, for which payment will be made, should be reasonably short and to the point,]

An Oil Strainer for Oil-Fired Furnaces

An ingenious and efficient strainer and cleaner device is discussed which provides for easy discharge of the separated impurities.

An important auxiliary of oil-firing equipment is an efficient strainer to remove every trace of solid impurities that might lodge in the burner nozzles. Many makes of gauze filter, whether of the single or the duplex type, have a number of inherent disadvantages, including wedging of the solid material in the gauze, with consequent tendency to collapse because of the pressure developed and the length of the time required for cleaning.

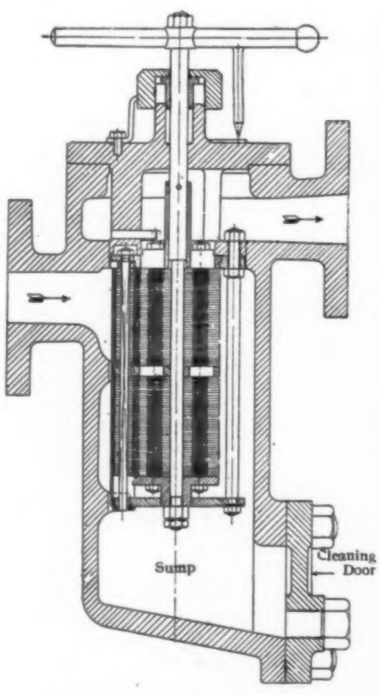
Considerable interest attaches in this connection to the latest design of "Clinsol" oil strainer, a production of J. Samuel White and Co., Ltd., Cowes (I. of W.), which is an advanced type of multiple plate or "edge" strainer, including an ingenious and efficient cleaning device with easy discharge of the separated impurities. Essentially, the arrangement consists of a small vertical closed cast iron or gunmetal cylindrical body, having a flanged inlet and outlet, which is installed in the oil supply pipe-line, operating either under suction or pressure, and formed at the bottom portion into a cleaning sump with discharge door.

Inside the body, filling a considerable part of the space, is assembled a pack of horizontal circular thin steel plates, fixed very close together, within a range of, say, 0·02 in.–0·005 in. space, attached to a vertical spindle projecting from the top through a gland and supported inside, above the sump portion.

The space between the circular plates is adjusted as required, say, according to the nature of the oil and the impurities, and the degree of filtration required by the insertion of packing pieces.

The oil enters by the inlet opening, travels horizontally through all the extremely narrow spaces between the plates, which prevent the passage of solid particles, and emerges in the clean condition at the discharge opening. An important point, especially in comparison with the gauze filter, is the great strength of the design, the standard strainer being able to withstand a pressure difference over the pack of as high as 60 lb. per sq. in., although incidentally it is never economic or good practice to work with such high-pressure difference.

For cleaning, there is fixed in the body a permanent assembly of stationary thin steel knives, each projecting into a corresponding aperture between two plates in the pack, which latter is caused to make a partial revolution, forwards and then backwards again, by hand operation of a handle at the top of the central shaft, so as to force out all the impurities lodged between the plates and deposited on the face of the pack.



Part sectional view of strainer.

For easy discharge of the latter, the circular plates are all constructed with a small portion cut out, which forms in the side of the pack a vertical deep channel, into which the dislodged impurities pass. This channel leads to the sump below from which the material can be taken out at convenient intervals through a cleaning door, provided with screwed studs or nuts. The arrangement is such also, by the use of special small pieces between the plates, that no oil can flow to the vertical discharge channel.

These standard strainers are available in a range of sizes, suitable for internal oil pipe diameters from ¾ in. to 4½ in., with a capacity of 820 lb.–28,000 lb. of oil fuel per hour under discharge conditions, and a distance of 0·01 in. between the plates, whilst for lubricating oil the duty varies according to the viscosity and the impurities present.

When operating under suction conditions the duties are about 33% less. Several slightly modified designs are also supplied for ¼ in.–½ in. pipe-lines, one of which is intended for petrol and paraffin, while it is sometimes possible to fit a "Clinsol" pack in the body of a gauze filter.

Manufacture and Characteristics of Hiduminium RR Alloys†

By J. TOWNS ROBINSON*

This is the second article of a series dealing with the manufacture and characteristics of Hiduminium RR alloys, and also some general aluminium alloys, written with the object of familiarising those in industry with the vital and important part played by these light alloys. In this article the author stresses the need for co-operation between designer and metallurgist, so that the application of each casting can be carefully studied and advantage taken of special characteristics of a particular alloy. The manufacture of castings is discussed with special reference to their soundness.

THE quality of aluminium alloy castings has improved enormously in recent times, due to the greater knowledge and advancement in foundry technique. Another very important factor which has contributed to a marked degree, has been the close co-operation between those responsible for the design, and the manufacturer. The importance of this co-operation cannot be too highly stressed, and is absolutely imperative for the guaranteed production of sound and high-quality castings. Too often in the past has the design been born without any due consideration for the man who has to make the final casting, or the inherent properties of the alloy, and bad design in combination with a totally unsuitable alloy, has resulted in disappointment with aluminium alloys, and in a general lack of faith in their applications. Experiments of this nature have often proved a costly business and left a sense of irritation between the designer and the foundry, which has naturally restricted both development and progress. This feature has been more applicable to the heavy engineering side of industry in which new problems have arisen where the use of aluminium alloys could effect a tremendous saving in weight with the advantage of greater efficiency and development.

Instances have arisen only too numerously in which the alloy has been well suited for the purpose, but the nature of the design has resulted in inefficiency, and the failure attributed to both alloy and foundry. The question has oft-times been asked: "Upon what golden rules can the designer design, and how can he assist the foundry?" This is a very difficult question to answer, and I doubt if anyone has yet introduced the golden rules.

This, therefore, brings in the paramount necessity of contact and co-operation between designer and metallurgist, with the result that each application or each casting can be studied individually. It is simply tradition that the foundry will tackle any casting, however difficult, and grumble that the design is terrible, and yet endeavour to produce a good-looking casting and feel that it has achieved its object. A casting which looks a "good 'un" may be embodied with the very spirit of Satan himself, and, given the opportunity, which is usually service conditions, will gladly impart the evil spirit with devastating consequences.

It must not be interpreted that the co-operation between designer and metallurgist is all that is required to produce sound castings, but only as a very important essential or basic principle to construct upon. It should ensure that the application of the alloy is sound, and the design is such as to assist and help the foundry in every way to take advantage of the natural characteristics of the respective alloys. It is here that the metallurgist's job starts, and again each casting must be individually studied to obtain soundness and uniform physical properties throughout, which can be guaranteed and produced under production conditions with the minimum of scrap.

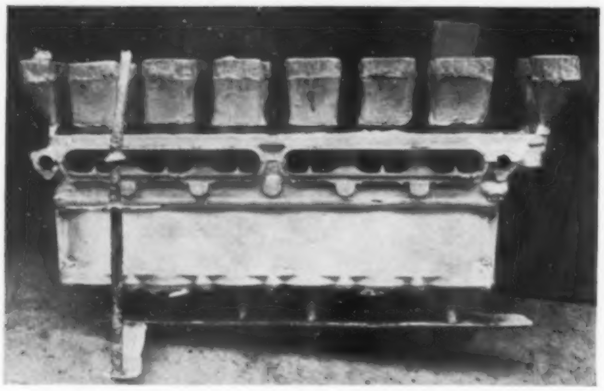
† Patented.
* Chief Metallurgist, High duty Alloys Ltd.

General view of the aero engine cylinder head section of the foundry at Messrs. High Duty Alloys Ltd.

The best method of running or making the particular casting must be first decided upon, but this in itself will not guarantee a successful casting, therefore, the first one produced, providing, of course, that it is dimensionally correct should be radiologically examined to detect any unsound areas or casting defects, then sectioned and submitted to a complete macroscopical and microscopical examination, and finally be tested for the uniformity of its physical properties. Of course, it often happens that the first casting produced, upon close inspection, reveals obvious defects, such as drawn areas, porosity or mis-runs. A study of the nature of these defects is therefore necessary, and should result in alterations being made to the method of running to obviate and correct them. A great number of factors and variables enter into the making of a casting, and each of these variables must be thoroughly understood, and their particular functions controlled in the correct sequence, otherwise it simply amounts to one feature reacting against the other. Each alloy owing to its particular make up or constitution of elements and arrangement or formation of those elements, needs treating in a specific manner to allow it to function naturally.

If the metal in the mould solidified instantly or uniformly at a constant temperature, then uniform distribution of constituents and properties would take place throughout the casting, but these conditions, unfortunately, do not exist.

Solidification of the alloys usually takes place over a very wide range of temperatures due to their constitution, and the natural restriction afforded by the changes in section of the casting. The first metal to solidify, therefore, has a tendency to draw upon the lower melting constituents in other regions in which the alloy is semi-solid. Naturally, adequate feeding must be provided to make sure that these



Aero-engine cylinder block casting in RR50 showing runners and risers.

areas are fed with liquid metal. In most alloys, liquid to solid shrinkage occurs by virtue of the fact that the solid metal occupies less volume than the liquid.

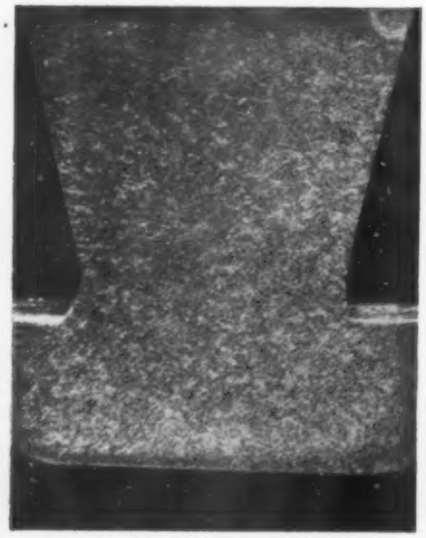
The geometrical form and dimensions of the casting are taken from the mould, and the total shrinkage of the outside skin of the casting is equal to the solid contraction which occurs in the metal cooling from the melting point. The shrinkage of the interior of the casting is, however, greater than this by the amount the metal shrinks during the process of solidification. Therefore, if feeding is neglected, each casting contains voids equal to the shrinkage of the metal during solidification.

A common and most troublesome feature alled to the correct feeding of a casting, is intercrystalline porosity, which occurs during solidification of the metal at the grain boundaries. This constitutes porosity of a type which is only rendered visible upon microscopical examination, and is termed micro-porosity. It can occur in certain definite affected areas throughout the casting, and is a potential source of weakness in the normal state, and is naturally aggravated if the casting is subjected to working conditions at elevated temperatures when cracking due to crystal boundary disintegration takes place under the imposed stresses. This form of micro-porosity is due to migration of the eutectic constituents during solidification, and can be controlled by the size of the risers, or, in other words, the correct feeding of the casting. In this case the casting can be quite free from pin-holing of the usual type, gas-free, and otherwise perfectly sound. It is necessary, therefore, to find an optimum size of riser to feed the areas generally affected. When the risers are too large, the metal is held for a prolonged period in a semi-liquid condition, and liquation of the eutectic occurs. If, however, the risers are too small, then the contraction cavities formed upon solidification are not fed properly, and remain as voids, the risers having solidified too rapidly to feed down to the affected areas.

The feeding of the metal into the mould is also of very great importance, and should be controlled in such a manner as to allow the metal to enter the mould slowly in a steady, uninterrupted stream. Turbulence and agitation of the metal must be avoided, otherwise oxidation will take place and the film of oxide formed will become intimately broken up and intermingled in the metal, with the result that particles of oxide will be deposited around the grain boundaries upon solidification. This will naturally cause grain-boundary weakness, and hence a lowering of the physical properties and general unsoundness upon pressure testing. It is advisable to run the casting from the bottom by means of multiple gating, the metal entering the mould through a reasonably small downright leading into the gates to allow the metal to rise slowly and uniformly through the casting into the risers. The manner of running the casting relative to the distribution of the risers, etc., has an important bearing on the pouring temperature, and it is imperative that the pouring temperature should be as low as possible, so that as soon as the risers are full, solidification should take place quickly and uniformly.

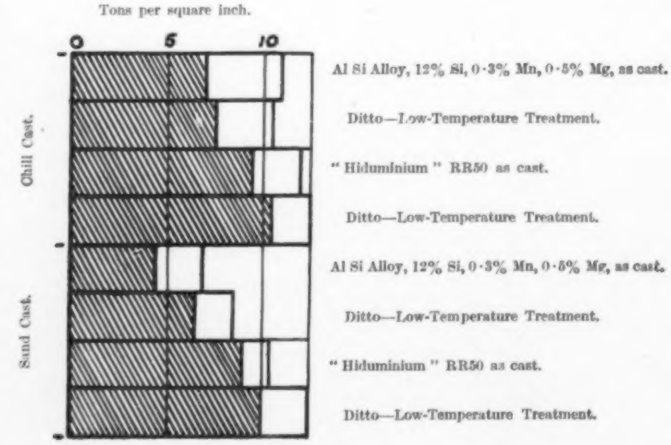
Another important aspect in foundry technique is the question of a suitable sand, and the control of same. In the past, sand has received very little attention or consideration, with the feeling that any sort of sand will do providing that it is sand, so that the question has been left to the moulder's own ideas, his control consisting of his hands and a watering can. In the first instance, a suitable grade of sand must be decided upon and checks instituted to ensure the quality of supplies, and then standard conditions ascertained relative to mechanical grading, moisture, permeability, compression strength, hardness, etc., and the control of these conditions placed upon a routine basis. Probably more pitfalls have occurred due to a lack of knowledge of sands than any other feature, and many times the metal has been blamed, whereas the sand has been the cause of the trouble. For

Macro-etched section of a riser from a casting in RR50, showing fine even crystal grain size and distribution of constituents.



COMPRESSION TESTS.

Specimens cut from bars 1 in. diameter × 6 in. long.
Cast in standard sand and chill moulds.
Size of Test Specimen 0.5 in. diameter 1 in. long.
SHADED AREA REPRESENTS 0.1% PERMANENT SET.
OPEN AREA REPRESENTS 0.5% PERMANENT SET.

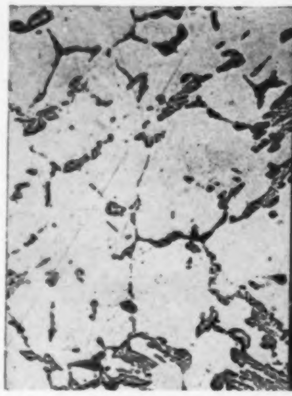


instance, in the writer's experience astounding figures have been found on the compression strength of cores brought to light upon investigation of cracked castings. Foundry suppliers have been very prone to supply their own particular type dressings or mixtures, etc., and to guarantee to cure all evils, with very little knowledge of their own products. Daily moisture tests can now be carried out on the foundry floor in a few minutes only, with easily-manipulated apparatus, such as the "Speedy Moisture Tester," which places the matter beyond doubt. In fact, these standard conditions can be carried out much more easily and with far less trouble than the old chance-to-luck methods. For aluminium alloys a fine-grain sand of the Mansfield type is advisable, having a low clay content with sharp angular grain formation. The new sand should constitute roughly 50% 85 mesh, 30% 20 to 40 mesh, and 10 to 15% 100 mesh, the remainder being "fines," which should be as low as possible. On floor sand after mechanical working, the "coarse" is slightly reduced, being 40 to 45% 85 mesh, and 25 to 30% "fines" over 100 mesh. The moisture content of the new sand should be 5 to 6%, and 4.5 to 5.5% on the floor sand with a permeability of 23 to 25 AFA, and a compression strength of 5 to 6 lbs. per sq. in. For castings of intricate design such as aero-engine cylinder heads with very fine deep fins, oil-bound silica sand-dried moulds should be used. Sand for cores should be a good silica of the Erith or sea-sand type with a binder such as linseed oil, Glyco or Dextrin, in the proportion of 1 to 2% binder and approximately 50-50 old and new sand. Core drying should be strictly regulated at a definite temperature and time, which must be found for each respective class of casting.

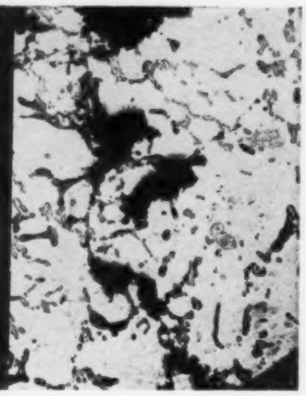
Melting furnaces offer a diversity of opinions, and melting practice is undoubtedly carried out under a likewise diversity of methods. The quality of aluminium alloys is greatly susceptible and influenced by these conditions due to their affinity for gas absorption and oxidation. At the present time, gas and oil are principally used as a means of firing, and undoubtedly afford a better means of control than the older methods employing coke firing. What is most probably the ideal condition, that is electrically-heated melting furnaces, has yet to come to a practical and economical production basis. Due to the mode of their application and weight per bulk, the problem of handling aluminium alloys on a large production scale by a foundry producing a miscellaneous range such as sand castings, ingots for sand castings, and ingots for forging extrusion or rolling purposes is not an easy one. This, of course, tends to the necessity of handling and melting quantities of fairly small weight, as compared with similar conditions in other industries.

Under these conditions, crucibles are chiefly employed, either in tilting or pit-type furnaces, and are made of plumbago or cast iron. The iron crucible is successfully used, and has a fairly long life, but has certain disadvantages and special precautions must be taken in cleaning. For instance, it is necessary in most cases that at the end of each day, the iron pot must be removed from the furnace, and thoroughly cleaned by scraping and recoated with a protective coating of whiting and water-glass before further use, owing to the encrustation formed of an iron-aluminium alloy on the surface. If this encrustation is not removed, trouble is bound to be experienced with hard spot inclusions of a minute character, particularly in such parts as pistons subjected to a very highly-polished machine surface. Special alloy steels such as chrome and nickel chrome are advocated for melting crucibles, but it is doubtful if they warrant the extra cost involved.

It has always been the practice of my company to use oil-fired tilting furnaces with plumbago crucibles, and having had experience of other types, I venture to say that these conditions cannot be bettered for accurate control and quality of metal produced. For the production of sand castings, it is preferable to start from ingot material of the desired alloy which has been made under conditions guaranteeing uniform chemical composition and freedom from segregation and gas content. By the use of ingots, much safer lower melting temperatures can be employed without the risk of gas absorption, which would necessarily occur if alloying took place in the same furnace prior to the pouring of the castings. With this method, it is really unnecessary to employ any of the various degasification or pre-solidification processes. Pre-solidification can be used to advantage in certain cases quite easily, but to be successful degasification must be perfectly controlled with a proper layout of plant and apparatus, otherwise, more harm than good will result. Therefore,



Micro-structure of heat-treated sand casting in the RR50 alloy. Unetched. × 100.

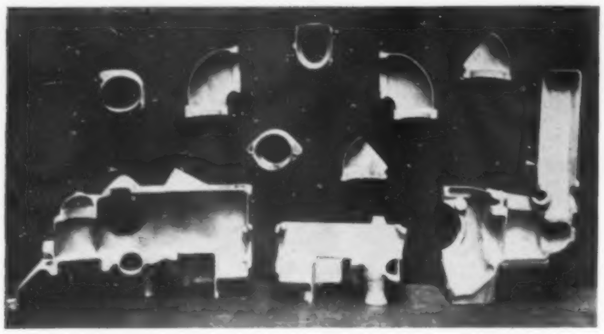


Micro-structure of heat-treated sand casting in RR50 alloy showing cavities due to lack of feeding and grain boundary weakness.

Bracket casting in RR50, weighing 5 lb.

TENSILE PROPERTIES OF SAMPLES CUT FROM HEAT-TREATED SAND CASTING.
(Test Pieces 1/50 sq. in. Cross Sectional Area.)

Position of Test Piece	Yield Point Tons per sq. in.	Ult. Stress Tons per sq. in.	Elongation % on 2in.	Brinell Hardness No.
1	11·0	13·0	5·0	72
2	11·5	13·0	5·0	72
3	10·5	14·5	5·0	72
4	9·0	13·0	8·0	72
5	10·0	14·0	7·0	72
6	9·5	14·0	5·0	72



Sand castings in RR50 sectioned to show how fine the wall thickness can be cast with perfect soundness.

the use of a flux such as the "Hiduflux," developed by my company, will ensure perfect cleansing and degasification.

Coming to the actual casting alloys themselves, the older types of alloy such as the copper-zinc-aluminium and silicon-aluminium, have practically died out. The modified silicon-aluminium alloy containing additions of magnesium and manganese such as the Beta and Gamma, have found favour, particularly on the Continent, but the greatest advancement has been made by the Hiduminium RR50 alloy. This alloy is very easy to cast, even in very thin sections, and attains its full physical properties after a low-temperature or ageing treatment only, which is a highly desirable factor when dealing with castings of intricate shape, and drastic changes of section. The alloy after this treatment is perfectly stable and free from internal or residual stresses induced by differential contraction of the various sections of the casting which occurs in alloys depending upon a high-temperature quenching operation for their properties. This means that all the natural characteristics of the alloy are available for the applied service stresses. In RR50, with the correct foundry technique, very good and uniform physical properties can be obtained throughout the casting. The chief characteristics of this alloy are high proof stress, fatigue strength, resistance to shock as designated by the "Amsler" repeated tensile fatigue test, and excellent creep properties which are naturally all-important and much superior to the silicon-aluminium types of alloy. This alloy has found wide application for highly stressed crankcases, cylinder heads, cylinder blocks, and other large and complicated castings, such as those employed at the present time in Diesel engine construction for marine purposes.

In a large aero-engine cylinder block cast in RR50 weighing 210 lbs. physical properties after the low-temperature treatment are consistently obtained of 9·0 to 9·5 tons per sq. in. tensile strength with 2 to 5% elongation throughout the casting after the taking of 12 test-pieces from varying sections. On a small casting such as a bracket as illustrated, weighing just over 5 lb., 13 to 14·5 tons per sq. in. tensile strength, and 5 to 8% elongation are again consistently obtained on six test-pieces from different sections. RR50 is very immune from hot shortness, and has a linear casting contraction of 1·042%—pattern maker's scale ⅛ in. Although RR50 is not so constituted as to be claimed to be suitable for use at elevated temperatures, it is of interest to note its physical characteristics at temperature.

Part of the sand testing section of Messrs. High Duty Alloys Ltd. Laboratories.

Hiduminium RR50 Sand Cast Bars.

Test Bars Cast to Rough Shape, and Machined to 0·564 in. Dia.

Tensile Strength at Elevated Temperatures Heat-treated. Low Temperature only. Temperature of Test.	Tons/Sq. In.	Tensile Strength After Heating at Temperature, and Cooling Down to Room Temperature again. Temperature.	Tons/Sq. In.
Normal.	13·00	Normal.	13·00
200° C.	11·30	200° C.	13·00
250° C.	8·80	250° C.	12·30
300° C.	7·0	300° C.	12·00
350° C.	4·70	350° C.	11·20

Brinell Hardness at Elevated Temperatures.

Heat-Treated. Low-Temperature Treatment Only.

Temperature of Test.	Hardness Number.	After Cooling to Normal.
Normal	76	—
100° C.	72	76
150° C.	57	76
200° C.	49	74
250° C.	37	69
300° C.	21	62

"Hiduminium" RR50 is also widely used for gravity die castings, and if amply fed, is particularly easy to cast, and its freedom from hot shortness already mentioned renders it free from incipient intercrystalline cracking. The presence of the requisite amounts of silicon and titanium produce in the chill cast condition, an extremely fine and uniform crystal grain throughout the various sections.

The reliability of Hiduminium RR50, whether in the form of sand- or die-castings, has been proved under the most gruelling stresses in service in the various branches of engineering.

Lloyd's Register Scholarship in Marine Engineering

The General Committee of Lloyd's Register of Shipping have awarded a scholarship of the value of £100 per annum, tenable for three years at a British university, to Mr. John A. Smith, an apprentice engineer of Messrs. Vickers-Armstrongs, Ltd., Barrow-in-Furness, and a student of Barrow Technical College.

The scholarship is awarded under the auspices of the Institute of Marine Engineers on the results of this year's examination for student membership of the Institute.

Canadian Iron and Steel Production

During the first half of 1937, the steel industry in Canada showed a striking acceleration in its operations, the output of steel recording a gain of about 23%. The increase in pig iron production was nearly 25%. The volume of steel ingots during the first six months of 1937 was 713,000 long tons, while the output of pig iron was 424,000 tons. The index of employment based on monthly returns from the principal firms in the iron and steel group averaged more than 15·3 % higher than in 1936. The average standing of the index was 104·2 against 90·4 in the preceding year. The recovery of the steel industry from the low levels of the early part of 1933 was one of the striking features of the last four years.

Direct Blast Smelting of Poor Gold Residues

By C. C. DOWNIE

The economical reduction of the poorer classes of gold residues to obtain the maximum recovery of the precious metal has been given some attention of late, and in this article the author describes the advantages of direct blast smelting in comparison with other methods.

THE direct smelting of the poorer class of gold residues, and " sweeps " collected from numerous sources, is conducted nowadays by blast-furnace smelting. Previously this was done on reverberatory hearths, and only the slags from the latter worked off in the blast-furnace. The use of the reverberatory hearth is still retained for smelting rich gold materials, such as rich slimes from electrolytic plants, platinum residues, etc. The reason is that a more rapid return can be obtained from a small charge worked on the reverberatory furnace, as the rich lead product can be cleaned and transferred to the " test " furnace for cupellation on short notice. With the blast-furnace process, the residues require to be briquetted and operated on a larger scale. The lead recovered is greater in bulk, takes longer to clean, and occupies a lengthier period on the cupellation hearth.

The great advantage of the blast-furnace smelting, however, is that all classes of poor material, together with fume, and accumulated works residues may be recovered in concentrated form, whilst the slags go to waste. Reverberatory slags are invariably rich, and necessitate re-smelting in the blast-furnace. The decision as to whether the smelting has to be performed in the reverberatory or the blast-furnace, depends upon the monetary value of the material on hand. In British money, material of more than £200 per ton in value, is usually worked on the reverberatory furnace, whilst all residues less than this figure are briquetted and smelted in the blast-furnace. The richer materials embrace concentrates from mining concerns throughout the world, together with " sweeps " from mints, large manufacturing jewellers, goldsmiths, silversmiths, and other workers in precious metals. A short account of the reverberatory furnace process will be of interest.

The Reverberatory Process

All the purchased residues require to be very thoroughly sampled for assaying purposes, and this necessitates a preliminary fine grinding. Fine material can seldom be smelted with the same ease as coarser masses, but the conditions of sampling do not permit of any latitudes being allowed. After grinding on pan mills, the rich mass is wetted to prevent loss by particles being blown away by the wind. The only additions made are some sulphur material to form a layer of matte, and fluorspar to act as flux. These additions are well mixed and charged into the furnace.

A few hundredweights of arsenical lead, and some poor matte, are placed on the bottom of the furnace, and the fine residues charged on top of this. Coal-fired reverberatories, furnished with firebrick linings are used, and as the work calls for no smelting skill, is carried out by unskilled labour. The products are a rich lead containing practically all the gold and platinum, etc., an enriched matte and a comparatively rich slag. The assays in ounces per ton are as follows :—

Lead.—4,000 oz. to 8,000 oz. silver, 240 oz. to 400 oz. of gold, 20 oz. to 30 oz. of platinum.

Matte.—1,000 oz. to 1,800 oz. silver, 12 oz. to 15 oz. of gold, 2 oz. to 4 oz. platinum

Slag.—70 oz. to 100 oz. silver, 4 oz. to 12 oz. gold, nil up to 4 oz. platinum.

The object in using arsenical lead in place of ordinary lead is to follow the principle introduced by D'Hennin some 50 years ago—namely, that arsenic will remove iridium, and the associated metals of the platinum group in the form of a crude speiss which is skimmed off. If this addition is not made, the tendency of the heavier platinoid metals is to sink into the bed of the furnace, and even with this addition, the old bottoms contain appreciable amounts of osmium. On removing the lead to the usual cleaning furnace, and skimming at both low and high temperatures, these rich products are recovered, whilst the lead containing the gold, silver, and the bulk of the platinum and palladium remain in the lead, which is cupelled in the usual manner. The skimmings contain practically all iridium, osmium, ruthenium, and rhodium contained in the original residues. These are concentrated by repeated sulphurising and ultimately subjected to wet methods of separation.

The reverberatory matte is roasted at about 700° C. according to the ancient Ziervogal process, the soluble products recovered by the Ottokar Hoffmann copper sulphate process, and the silver precipitated on copper sheets, following the Augustin system. The residues from the wet extraction retain all gold and platinum present in the matte. As the other constituents are chiefly iron oxide and lead sulphate, these residues make an ideal material for fluxing the briquettes used in the blast-furnace process. The fume which escapes from both reverberatory and blast-furnaces carries an appreciable percentage of the small arsenical content of the lead. This is recovered in the condensers, and on smelting this fume, arsenical lead is regained for future use with fresh consignments of bought residues.

Briquetting for the Blast-Furnace

The poorer class of residues, concentrates, " sweeps," etc., are subjected to fine grinding for sampling purposes in the same manner as with the reverberatory process. In the case of poor Rand sweeps which apparently are the product from old melting crucibles, much alumina is present, together with graphite. Other materials also show refractory properties, and hence it is considered a good plan to mix the different residues as far as possible. For example, certain slimes from electrolytic copper refineries, etc., contain oxidised products which assist in the oxidation of carbonaceous matter.

Other materials, such as jewellers' and goldsmiths' " sweeps," contain lime and iron oxide from the polishing powders used, and these assist in the fluxing of alumina. The sources of the poorer materials are almost innumerable, as many of the large mining and smelting firms, mints, and electrolytic refiners appear to be more intent on dealing with the concentrated products, and sell off the by-products. In converting these finely ground materials to briquette form, care must be taken that the latter possess comparatively simple fusing properties. Earlier methods consisted of briquetting without much regard for physical properties, and then smelting these in the blast-furnace with a considerable excess of foul slags. Whilst this method partially succeeded, much trouble was experienced by frequent choking of the furnace, due to the formation

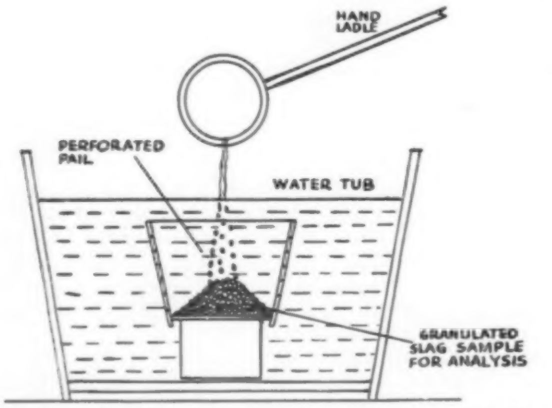
of infusible masses. Hence the briquettes are to-day made up with the addition of the requisite proportion of iron oxide and lime, etc., to ensure easy fluxing conditions. This has to be done individually on all lots briquetted, and is checked by periodically noting the melting point of a selected briquette in a small crucible. This test also shows whether a sufficiency of sulphur is present in the mass for a suitable matte to be formed without the addition of the usual pyrites, or salt cake.

The mass to be briquetted is thoroughly mixed up with some 10% water containing 2% of water-glass. The proportion of water-glass has sometimes to be increased, depending on the adhesive qualities of the residues. The briquetting is done in small, mechanically-operated machines at a pressure of about 1 to 1¼ tons per sq. in. The briquettes produced at this pressure are not particularly firm, and are transferred to adjacent flues for drying. When dry, they are transferred to the blast-furnace.

It is known that many of these poor concentrates, electrolytic slimes, "sweeps," etc., contain iridium, osmium, rhodium, and ruthenium, but they are present in such minute proportion that they cannot be determined quantitatively. Hence the precious metal smelter often finds his concentrated products with numerous valuable constituents which were not even paid for.

Smelting in the Blast-furnace

To those acquainted with the blast smelting of lead, copper, and nickel, there is nothing outstanding in the smelting of briquettes of precious metal residues, but the products are of much higher monetary value. Rectangular



System of taking slag samples for assay and analysis.

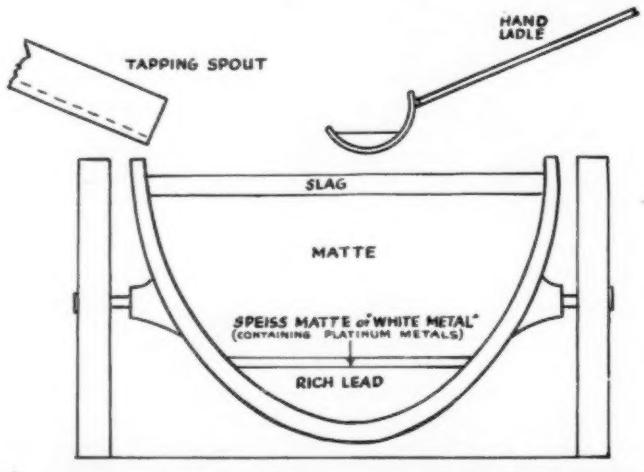
water-jacketed blast-furnaces of old design are employed, and there is seldom a sufficiency of material on hand to keep them working over the week-ends. No attempts are made at applying modern methods, such as mechanical charging or tapping, simple water-jacket design, or improved blast control. The charges have, however, to be worked with accuracy to ensure that the slags are produced in clean condition, and readily fusible, together with the necessary lead, and a matte containing upwards of 30% copper to suit the subsequent wet process of the latter.

In starting up the furnace, the bed charge consists of coke, on top of which is placed foul slags, with or without the addition of a little lead or poor matte. The kindling is carried out in the usual fashion, care being taken that the blast spreads the ignited mass as widely as possible. That is efforts are made to prevent "cold-spots" forming in the crucible, as the lead and matte periodically tend to solidify in the bottom, particularly if little arsenic and antimony are present. A clean crucible throughout the operations usually indicates the presence of the latter metals, either in the lead, or in the form of speiss-matte.

Once the tappings come freely from the hearth, a fixed proportion of briquettes is added, and this is successively increased, until the maximum is reached. Odd waste materials in the form of old furnace linings, ashes, excavations from old plant, etc., are added in small proportion to the charges. Limestone is added to reduce the silver content of the slag, and fluxes the high alumina content. Where the slags are too foul, and the matte unduly rich, a somewhat infrequent practice is to add some sulphur residues. In the case of "sweep" from the Rand mines, containing much alumina and graphite, salt-cake is a useful sulphur addition agent, as it assists in the oxidation of the carbon.

The successful fluxing of alumina at comparatively low temperatures depends more on adhering to the ratios of the different constituents in the slag. The slag runs continuously from the slag hole, and when the presence of matte is shown by the altered flow of the former, it is tapped into ladles together with the lead. The tap-hole is simply opened by means of hand-picks and "pinches," and small hand ladles are used to withdraw the rich lead which flows out first. After most of the lead has been removed in this way, the matte is allowed to fill up bogie-ladles which lie in position beneath the hand-ladles. The matte is then run into ingot moulds. Slags which have shown the evidence of matte being present are returned to the furnace for re-smelting.

There are various small practical points in working the charges rapidly, and accurately fluxing to give a fluid slag, and yet maintain a comparatively rich matte. It is an easy matter to introduce a large excess of lead, and sulphur additions in the form of salt-cake, or pyrites, etc., but the result is that unduly diluted products are obtained



Samples of metal or matte are taken in hand ladles, poured into small moulds, and removed to laboratory for assay and analysis.

which take longer to treat for precious metal recovery. When it does happen that some raw materials are secured, which prove difficult to smelt successfully, this system is adopted as the last resort.

Products of the Smelting

When operating the charges, the amount of lead pigs formed is a fairly good indication of the richness of such metal. If too little lead forms, additions of lead ashes should be made to the charges, which become reduced to metallic lead, and incidently assist in the oxidation of graphite and other carbonaceous constituents. It is generally considered a good feature to have a fair amount of copper present, so that an appreciable layer of matte will cover the lead, and not offer much opportunity for the slag to become enriched.

In the same way as the products from the reverberatory furnace were represented by lead, matte, and slag, so also are the products from the blast-furnace secured, but in

place of the crude speiss or speiss-matte being skimmed off from the lead, a partial separation takes place in what are known as "pot-bottoms." The latter are simply the skins which remain on the ladles after pouring the matte into moulds. This does not mean that the lead does not require to be cleaned to remove the arsenical precious metal skimmings. The partial separation introduced by the removal of the "pot-bottoms" means that a less lengthy cleaning of the lead is necessary. A good average of the charges worked per week is as follows :—

Foul slags	42 tons
Briquettes (containing 45% "sweep," etc.)	35 "
Extras (furnace linings, ashes, etc.)	24 "
Coke	14 "
Matte	7–9 tons
Lead	1½–3 "
"Pot-bottoms"	1 "
Slags	60 "

Blast-Furnace Charge Sheet.

—	1. Cwt.	2. Cwt.	3. Cwt.	4. Cwt.	5. Cwt.	6. Cwt.	7. Cwt.
Slags	42	60	60	55	50	50	50
Briquettes	—	30	45	50	55	55	55
Ashes, furnace linings, etc.	—	—	4	5	6	6	6
Limestone	—	11	11½	12	12½	12½	12½
Pyrites, etc.	—	—	—	—	½	1	—
Coke	24	16	16½	17	16	17	16
Assay of Slag:— Oz. silver per ton	4	4½	3	5	6	4	3½

Totals..
Lead ....
Matte ....
Pot-bottoms ....
Slags .. ..

The lead and matte from this are tapped about every 2 hours, and the weight per tapping may vary from 2 cwt. to 6 cwt. The small briquetting plant turns out some 9 tons of briquettes per day to feed the furnace. During the process of blast smelting a very considerable reduction in bulk occurs, and the products recovered from the above are as follows :—

Composition of Briquettes.

	%
Rand sweep	28
*Other "sweeps" and residues	17
Flue dust	8
Works excavations	7
Rich furnace slags	8
Crude works litharge	3
Limestone	16
Iron residues (from Hoffman process)	13
	100

* These refer to smaller lots from different odd sources :—Kastenuber and Lehar, Goldschmidt, Baker, Perth Mint Refinery, Newalls, Kodak, slimes from innumerable electrolytic refineries, etc., etc.

Blast-Furnace Slag Analysis.

	%
Silica	33
Alumina	17
Ferrous Oxide	14
Lime	26
	90

The remainder of the slag is made up of base metals, carbon, etc.

An excessive amount of "pot-bottoms" is often due to matte solidifying to the sides of the ladle, and not properly representing speiss-matte, or white-metal. In such cases the mass is passed through the blast-furnace at the final charges, and this offers a good opportunity for the excess matte to separate. Any iron which separates out in the bottom of the furnace tends to contain iridium, osmium, etc.

The slags from each shift are sampled and assayed. When these are beyond a certain margin, depending on the market price of the precious metals, they are returned to the blast-furnace for re-smelting. Clean slags only showed some 4 oz. of silver per ton, and these were generally removed to waste. It usually paid to re-smelt slags containing upwards of 7 oz. of silver per ton, as it was considered that other small amounts of precious constituents justified this work. The worst slags on record seldom exceeded 10 oz. of silver per ton, and this was entirely due to careless furnace handling. The assays are generally done on ¼ assay ton, and after cupellation the prills are examined. Should black specks appear on the surface of the small silver prills, this is due to the presence of iridium, and all such slags are returned for re-smelting. The composition of the products are as follows, in ounces per ton :—

Lead.—2,000 oz. to 5,000 oz. silver, 60 oz. gold, 5 oz. platinum.

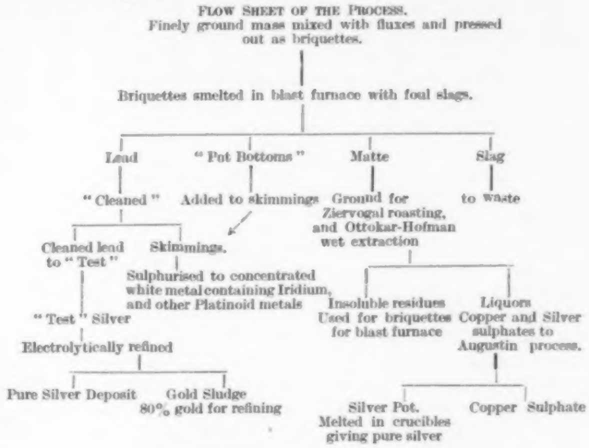
Matte.—950 oz. silver, 6 oz. gold, 0·2 oz. platinum. (30% copper, 12% lead.)

"*Pot-bottoms.*"—1,130 oz. silver, 6 oz. gold, 1·8 oz. platinum, 0·4 oz. of iridium, etc.

Slags.—4.4 oz. silver, 0·041 oz. gold, 0·009 oz. platinum.

A close examination of the slags revealed that they contained from 0·003 oz. to 0·014 oz. of iridium, and from 0·004 oz. to 0·010 oz. of palladium. The point at which the silver prills from the slags displayed the black specks indicating the presence of iridium was not definitely established, but when the market price of this metal was high, all such slags were resmelted.

Flow Sheet of the Process.



Treatment of the Products

Although the slags were known to contain other constituents which could have been recovered, they were removed to the dump as so much waste. The matte was passed through breakers, and ball-mills, and mixed with the matte from the reverberatory-furnace process for the same wet treatment.

The lead was generally more impure than reverberatory lead, and took longer to clean, giving a larger proportion of arsenical skimmings. This meant that the latter skimmings required more subsequent sulphurising in order to reduce to a concentrated speiss.

The "pot-bottoms" are added to the skimmings for sulphurising.

In this way the lead which has to go to the "test" furnace for cupellation is free from the heavy constituents, such as iridium, osmium, ruthenium, and rhodium, which otherwise would sink into the bed. The silver from this blast-furnace lead is refined electrolytically, and the anode sludge contains the gold, platinum, and palladium. The latter sludge seldom, if ever, contains any appreciable amount of the heavier constituents, as the arsenic removes them with great precision, as originally worked out by D'Hennin.

In conclusion, it should be remarked that despite the expensive nature of the materials smelted, the work is conducted throughout by unskilled labour. It is soon proved that little practical experience is really necessary. The great density of gold and its associated platinum metals ensure their sinking through slag and matte alike, in a manner unknown to other metals, with comparatively little risk in the nature of combination. Hence the smelting of precious metal residues probably represents the simplest form of pyro-metallurgical work conducted at the present time.

The Management Committee of the Copper Development Association announces that Mr. D. P. C. Neave, who has been General Manager and Secretary of the Association since its inception in 1933, is resigning at the end of the present year. Mr. G. W. Preston, the Association's electrical engineer, has been appointed to become general manager, and Dr. S. Baker, now assistant secretary, will become secretary.

Non-Metallic Elements in Steel

The Effect of Hydrogen

Much work has been carried out to increase our knowledge on the effect of non-metallic elements in steel. Experiments carried out recently show how detrimental an effect hydrogen can have on the properties of steel, and in a recent lecture on the subject before the Staffordshire Iron and Steel Institute, Mr. T. G. Bamford, M.Sc., stated that its detrimental influence is due to the formation of molecular hydrogen or hydrogen compounds formed in the steel under pressure. An abstract of Mr. Bamford's views is given in this article.

A LARGE number of practical experiments recently carried out in Germany have proved what a devastating effect hydrogen can have upon the properties of steel. It has long been known that nascent hydrogen will diffuse through iron in accordance with Finck's linear diffusion law—

$$dS/dt = kdc/dx$$

where dS is the quantity of gas diffusing in time dt, and dc/dx is the concentration gradient, while k is the diffusivity constant.

Gases diffuse through metals in the atomic and not in the molecular state. In the case of hydrogen and iron, diffusion is a lattice process and the grain boundaries play no part, except perhaps that they provide active centres for absorption and facilitate the entry of the gas. Whenever it passes into a contraction cavity, a blowhole or non-metallic inclusion, it becomes converted into molecular hydrogen, in which form it cannot diffuse, and will develop great pressure within the metal. Pickling blisters, surface defects on galvanised sheets, scale markings on enamelled sheets, hydrogen brittleness after soldering, and gas welding are well-known examples of faults traceable to the formation of molecular hydrogen under pressure.

Even with very low carbon steels, absorption of hydrogen gas from acid solutions causes a sharp decrease in deforming qualities and steels containing 0·90% carbon become quite brittle, like glass. Since it is only atomic hydrogen which can dissolve in molten steel, and since it is only at high temperatures that molecular hydrogen is ionised or converted into atomic hydrogen at the metal surface, it follows that molecular hydrogen has no solubility at room temperatures, and that while it can dissolve at high temperatures, its solubility in steel decreases rapidly with fall of temperature. The gas taken up in the annealing furnace by steel from gas mixtures containing hydrogen, will, if retained in it by rapid cooling, create intense internal stresses with resultant deterioration of properties. Gas taken up in this way has therefore essentially the same influence as gas absorbed in the pickling process. There is this difference, however, the gas can escape if cooled slowly from the temperature at which it was absorbed, and little harm will result, unless the dissolved gas is expelled too quickly.

Of special importance is the behaviour of hydrogen taken up by steel in the molten state. In order to investigate this, Bardenheuer made up in the high-frequency furnace a series of experimental melts with different carbon contents. After adding manganese and silicon part of the melts were cast. Before casting the second series, hydrogen was led through the molten steel for 10 mins. The first series were all quiet in the mould, but the second series were all turbulent and rose in the mould. In all cases the untreated steels forged easily. Nickel-chrome steels with about 1·0% chromium and 3% nickel seem to be equally susceptible to damage by hydrogen gas taken up by the molten metal. From melts of this alloy treated like the straight carbon steels, the untreated steel is quite sound, but whether forged directly or after cooling and forging at 1,000° or 1,250° C., the metal which has been subject to hydrogen treatment shows splinter flaws easily discernible in the plates after nicking and fracturing.

On the basis of his experience, the steelmaker lays great weight on a sufficiently long boil, since he knows that, failing this, a steel with bad properties will result. Particularly is it the case that a brittle steel can only result when large quantities of strongly rusted scrap have to be worked in and when a high carbon content has to be held, and a long boil must be avoided.

Rust differs from pure iron oxide essentially through its content of occluded hydrogen, and in fact a 1% addition of rust introduced 2·5 c.m. of hydrogen per ton of steel, or a volume equal to twenty times the total volume of the steel. Unlike hydrogen, carbon monoxide is almost insoluble in iron and steel, so that a lively boil is effective in driving out the greater part of the hydrogen from the bath. The carbon monoxide, bubbling through the math of metal, creates in the bath itself and in the atmosphere above it an atmosphere of carbon monoxide in which the partial pressure of the hydrogen is practically zero, so that the higher the pressure of this gas in the steel bath, as against the smaller partial pressure in the surrounding atmosphere, induces a tendency for hydrogen to pass from the former into the latter. In this way the dissolved hydrogen is slowly removed from the bath, and it should be possible to remove it if a long boil is possible.

Consequences very detrimental to the properties of the steel, however, can result from the introduction of hydrogen by additions made to the finished bath at a time when no further boil is possible and the injurious gas cannot be removed. For example, a steel is often spoiled by the addition at the finish of the heat of damp lime or ferro-alloys containing hydrogen. It is therefore strongly to be recommended that before adding ferro-alloys to the steel bath, all gas should be expelled from them by heating. Surface blisters which are essentially due to hydrogen completely disappear if raw limestone is used instead of the burnt product. Burnt lime will take up, on standing, 10% or even more of water, and in this way, introduce large quantities of hydrogen into the bath. The unburnt limestone, on the other hand, carries very little moisture, and through its content of carbon dioxide further stimulates the boil and the degassing of the bath.

Summing up, it may be said that whether hydrogen be introduced into steel in the pickling process while the steel is in the annealing furnace or during the processes of melting, in all cases its detrimental influence is due to the formation of molecular hydrogen or hydrogen compounds formed in the steel under pressure, thus weakening the intercrystalline cohesion of the grains Many unexplained defects in steel and cases of poor quality metal are due to this cause. Results obtained ought to warn us to attach more importance to the content of hydrogen in steel, not only from the point of view of steelmaking, but also of its further treatment in mill and workshop.

Nitrogen, strictly speaking, is incapable of dissolving in any solid metal in the same way that hydrogen dissolves in iron. It can only form nitrides such as Fe_4N, which can themselves form solid solution with the metal. Thus the nitride-forming elements, such as iron, chromium, aluminium, tungsten, and zirconium absorb nitrogen, while cobalt, copper, silver and gold do not. The absorption of molecular nitrogen by iron takes place only slowly, unless the surface has been activated which may occur in service as the result of abrasion, when the resultant hardening of the surface has been known to lead to failure.

The Micro-structure of Aluminium Magnesium Alloys

By E. MÖCKEL

Communication from the Research Laboratory of the Vereinigten Leichtmetallwerke, Hanover.

The aluminium-magnesium alloys provide an interesting example for a survey of the interrelation between the structure of the heat-treated alloy and corrosion behaviour. In this article, which is extracted from "Aluminium" and presented in a slightly abridged form, the results of an investigation on the micro-structure of several alloys are given to show the effects of heat and work under different conditions.*

CONSIDERABLE progress has been made in the development and application of the aluminium-magnesium alloys in recent years. The most common of these alloys to be applied to engineering are those in which the magnesium contents range from 3 to 9%. According to the constitutional diagram by E. Schmid and H. Siebel,[1] the aluminium crystal is able to dissolve 15·3% magnesium at 448° C., approximately 5% at 300° C., and 3% at 150° C. The magnesium which is not dissolved in the aluminium occurs as β crystal, Mg_2Al_3. In addition to magnesium, however, the aluminium-magnesium alloys used in practice also contain a small percentage of manganese, which has a useful effect upon the resistance qualities and enhances immunity to corrosion. Silicon and iron are present as impurities only within the limits usual with pure aluminium.

The preparation of sections for microscopic examination is effected in the usual manner for light metals. Various caustic agents are known, but all have not yielded entirely satisfactory results. Aqueous 10% NaOH solution will attack the Al-Mg alloys unduly; it is apt to produce corrosion of the cavities and therefore will not yield a clear picture of the structure. 10% chromic acid and 10 to 20% nitric acid, although they clearly reveal the β crystal in the cast structure, will fail where the α segregations are present in a very fine form—as, for instance, by tempering. A chromic and nitric-acid solution may be better in its effect, but very sensitive to temperature, and will therefore readily lead to over-etching and slight corrosion. The best caustic agent for aluminium-magnesium alloys was finally found to be an aqueous 9% phosphoric acid solution. For comparative investigation, however, it is indispensable accurately to maintain the etching duration, which was ascertained to be 30 mins. optimum, as also the concentration. The etching agent will reveal mainly the Mg_2Al_3 crystals, which are not to be recognised in an unetched section, and it delineates the Al-Fe-Mn compounds; Mg_2Si is stained dark.

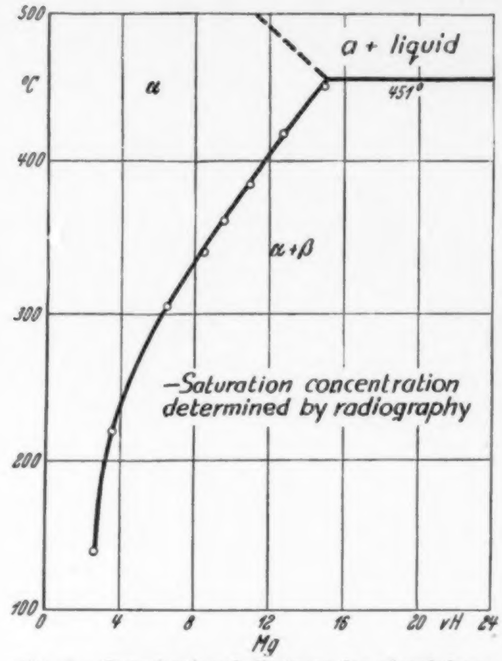


Fig. 1.—Constitutional diagram for aluminium-magnesium (E. Schmid and H. Siebel).

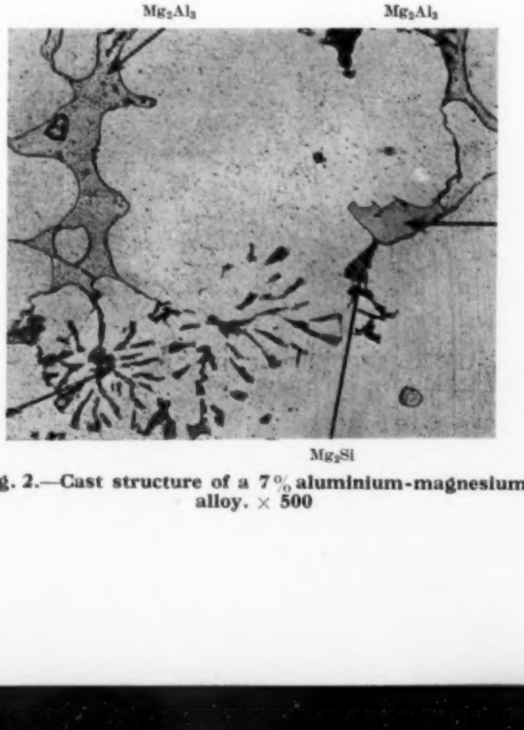
Cast Structure

In Fig. 2 is reproduced the cast structure of an aluminium-magnesium alloy consisting of 7·64% magnesium, 0·33% manganese, 0·11% silicon, 0·28% iron, and the remainder aluminium. The section was taken from the top of the casting, which, on the whole, cools down more slowly, and the structure solidifies more coarsely than at the bottom of the casting. The microphotograph shows different structure components. The base consists of mixed Al-Mg crystals; at the grain boundaries a pseudo-eutectic $Al-Al_3Mg_2$ has formed, due to grain liquation,[2] but, it will be noted, it does not appear as a eutectic, since the correlative aluminium has formed itself into the mixed crystals, and has left the Mg_2Al_3 behind at the grain

* July, 1937.
1 E. Schmid and H. Siebel. *Z. Metallk.* Vol. 33 (1931, p. 202.

2 Fuss. "Metallography of Aluminium and Its Alloys."..

Mg_2Al_3 Mg_2Al_3



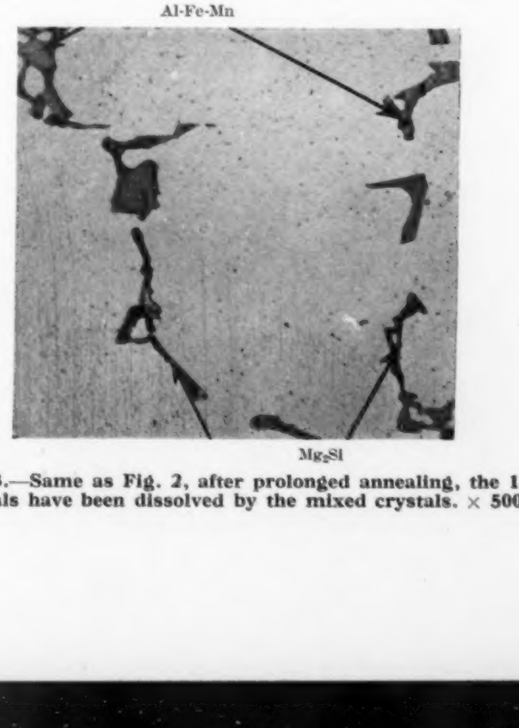
Al-Fe-Mn

Al_3Fe

Mg_2Si

Fig. 2.—Cast structure of a 7% aluminium-magnesium alloy. × 500

Al-Fe-Mn



Mg_2Si

Fig. 3.—Same as Fig. 2, after prolonged annealing, the 13 crystals have been dissolved by the mixed crystals. × 500.

Fig. 4.—Al-Fe-Mn in the cast structure of coarse segregations. × 500.

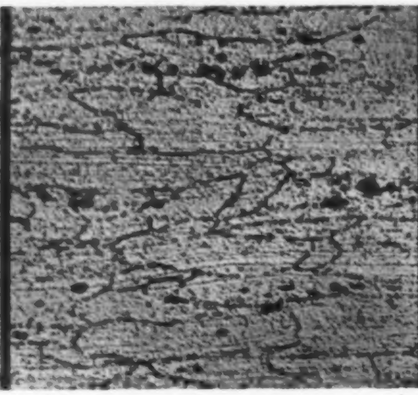


Fig. 5.—Showing sheet texture of rolling hardness. × 500.

Fig. 6.—Same as Fig. 5 after homogenising annealing. × 500.

limits as a brittle kind of crystal. In addition, Al_3Fe and Mn segregations may be recognised. By prolonged annealing it is possible to dissolve the segregated β crystals (Mg_2Al_3) almost completely in the mixed crystals. This will be noted in Fig. 3, in which is produced the microstructure of a similar section after prolonged annealing; the Mg_2A_3 has disappeared entirely, and what is left is only the Mg_2Si and Al-Fe-Mn crystals, insoluble in high-percentage aluminium-magnesium alloys.

Manganese forms a new structure component when iron is present in aluminium alloys. Its exact composition has not as yet been explored; it has been determined, however, that it contains much aluminium compared with iron and manganese. It is thus explicable that even in alloys with low content of iron and manganese coarse crystals of this Al-Fe-Mn compound are encountered, which is insoluble in aluminium and cannot be caused to disappear even after prolonged annealing. It is advisable, therefore, not to increase the manganese admixture beyond 0·3–0·4%, and to keep the iron admixture as low as possible, in order to obviate an unduly large proportion of these coarse segregations.

Fig. 4 shows a group of these Al-Fe-Mn crystals in the cast structure of a 7% aluminium-manganese alloy. The crystals are irregularly shaped, yet the square or angular shape predominates in the cast condition. In an unetched section they are to be recognised as delicate, bluish crystals; by etching with 9% H_3PO_4 they appear sharply defined, the colour changes but slightly, it is bluish grey, and readily shows a tinge of brown.

In high-percentage aluminium-magnesium alloys all silicon is bound to magnesium in the form of Mg_2Si, and since, according to Hanson and Gayler,[3] in the presence of 8% there is no more solubility of Mg_2Si in the aluminium; as the silicon content increases so also will the proportion of the brittle kind of crystals M_2Si. As an unduly high content of Mg_2Si greatly diminishes the working qualities of the aluminium-magnesium alloys, it is indispensable to keep the silicon content as low as possible. Aluminium of the highest possible purity is therefore selected as the initial material for such alloys. The Mg_2Si crystal appears in the cast condition in the typical form of Chinese lettering. After polishing with suspended magnesia, it may be recognised in an unetched section by its Turkish-blue colour. If etched with 20% HNO_3 and with 9% H_3PO_4, it will be stained brown or black.

Structure of Rolled Sections

The further treatment of the cast ingots is carried out, according to the final product required, either in the rolling mills or the press. As the aluminium-magnesium alloys are difficult to deform, especially those with high magnesium content, several intermediate annealings are required. The optimum annealing temperature found was 350° to 380° C.

The structure of a sheet, of a hardness as rolled, is shown in Fig. 5. It will be noted that Mg_2Al_3 crystals are segregated at the crystal boundaries. The direction of rolling is clearly seen from the stretched arrangement. By annealing above the line of solubility and subsequent quenching, all Mg_2Al_3 is caused to dissolve in the basic aluminium mass. The material is then in the homogeneous condition as in Fig. 6. By homogeneous is denoted that condition in which segregations of Mg_2Al_3 are to be found after etching for half an hour with 9% phosphoric acid neither at the grain boundaries nor in the grains. Only

3 Hanson and Gaylor. *Inst. of Metals*, London. Vol. 26, pp. 321-359.

Fig. 7.—Fixture of an extruded 9% alloy rod of press hardness. × 500.

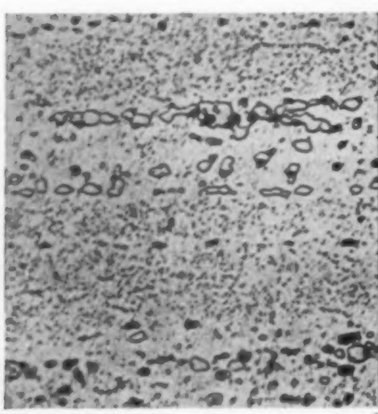


Fig. 8.—The same test piece as shown in Fig. 7 after homoganising annealing. × 500.

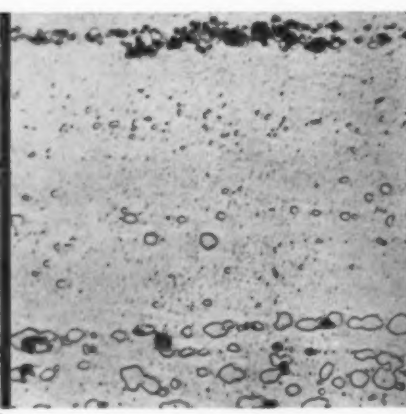
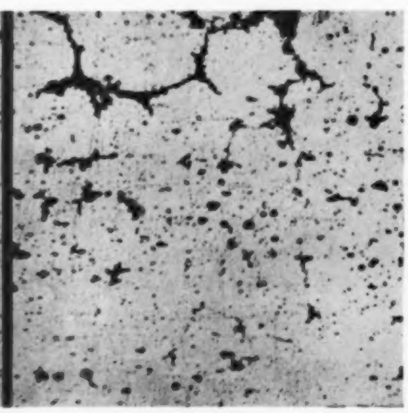


Fig. 9.—Sheet test of a 9% alloy, after annealing at 565° C. showing severe rents caused by overheating. × 500.



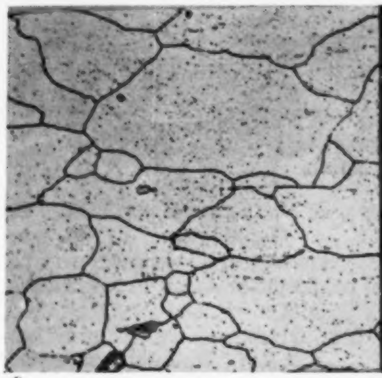


Fig.10.—Thread-shaped β-segregations caused by tempering for four days at 100° C. × 500.

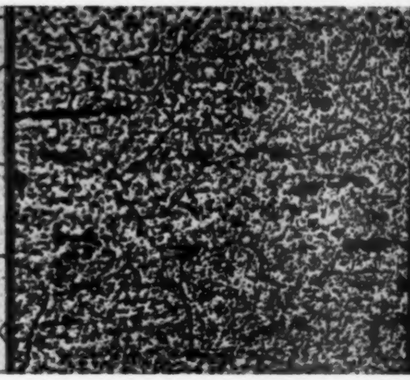


Fig.11.—Appreciable β segregations in a 7% alloy test after tempering for nine days at 200° C. × 500.

Fig. 12.—Sheet test of a 7% alloy, homogenised and deformed 20% by cold rolling prior to tempering for 27 days at 100° C. × 500.

the crystals Mg_2Si and the Al-Fe-Mn compounds remain undissolved, as already mentioned, in the presence of approximately 8% magnesium. In a homogeneous condition aluminium-magnesium alloys display their maximum corrosion proofness.

The micro-structure of a 9% aluminium-magnesium alloy bar is shown in Fig. 7. It has been extruded and subsequently cooled in air after pressing without further heat-treatment. The effect of annealing on this test-piece is shown in Fig. 8.

As with the aluminium-copper-magnesium alloys, overheating phenomena will attend excessive annealing temperatures with the aluminium-magnesium alloys. Comparative trials with test-pieces of 7% and 9% magnesium have shown that the high percentage alloys are more sensitive to overheating than those of lower content. At an annealing temperature of 535° C. no kind of combustion phenomena were recognised on the 7% alloy. The 9% alloy, after annealing at 565° C., is shown in Fig. 9. Overheating is noticeable by the severe formation of clefts and incipient melting of the crystals. It affects the resistance properties and the working qualities in a very detrimental manner, which cannot be remedied by any subsequent heat-treatment.

Tempering Effects

The solubility of magnesium in aluminium is not more than 2·5% at room temperature, therefore these alloys of higher magnesium content, if in homogeneous condition, are heavily oversaturated at room temperature. If such alloys are heated to temperatures at which the atomic mobility is great enough to allow of a decomposition of the oversaturated solution, segregations are bound to form from these crystals. After ageing test-pieces of 7% and 9% magnesium at room temperature, segregations were in no case observed. Not until after prolonged tempering at advanced temperature (e.g., 27 days at 75° C.) will initial segregation of β crystals occur at the grain boundaries. The micro-structure of a 9% aluminium-magnesium alloy, which was tempered after homogenising for four days, is shown in Fig. 10. Tempering has brought about the filiform segregations, which lead to intercrystalline corrosion. Increasing the temperature and extending the duration of tempering causes the segregation of the β crystals to progress further. This is illustrated in Fig. 11, which shows a specimen containing 7% magnesium after 9 days tempering at 200° C. Severe β segregation will be noticed, not only at the grain borders, but also in the grains.

At even higher tempering temperatures (300° C.) the Mg_2Al_3 crystals conglomerate into coarser segregations. By cooling down the 7–9% aluminium-magnesium alloys to approximately 300° C., immediately following the homogenising annealing treatment, and by keeping them at this temperature until a uniform β segregation is produced, the so-called pearl string texture will develop. This texture shows comparatively good resistance to corrosion, by tempering at 100° C.; however, the filiform segregations, previously mentioned, will develop.

Test-pieces deformed cold and tempered after homogenising,[4] are much more sensitive to tempering than ordinary sheets not deformed in the cold condition. A test-piece of the latter only shows filiform β segregations at the grain boundaries, whereas the re-rolled texture displays, in addition to the thread-shaped separations, also severe segregations within the individual grains, as shown in the specimen Fig. 12, which was rolled cold by 20% prior to tempering. This phenomenon occurs very clearly at certain degrees of deformation, at which the Mg_2Al_3 crystals then separate out from the over-saturated mixed crystals along the sliding or slipping lines and surfaces.

4 Roth. "Kraftwirkungsfiguren ou Al-Mg. Knetlegierungen." *Metallk.* Dec., 1936.

Strength of Tin-Base Bearing Alloys

DATA about tensile and Brinell tests on typical tin-base bearing metals, and on alloys made by adding cadmium to them in varying proportions, are given in a report of researches by C. E. Homer, B.Sc., Ph.D., and H. Plummer into the "Mechanical Properties of Some White Bearing Metals and Other Tin-base Alloys at Various Temperatures." Up to 3% addition of cadmium causes an improvement in strength and hardness, but above this amount these advantages are offset by loss of ductility. The extra strength due to the cadmium addition is retained by the alloys when heated, although these alloys, like nearly all the others examined, lost a definite proportion of their tensile strength when raised to a given temperature. Alloys of tin, copper and cadmium without antimony do not appear to have any particularly useful properties which cannot be obtained more easily in other alloys.

Another contribution on the subject of tin-base bearing metals is given in a work by H. Greenwood, M.Sc., on "The Tensile Properties of a Series of White-metal Bearing Alloys at Elevated Temperatures." Because the temperature of bearings when working may be much above that of the air, it was decided to examine the tensile behaviour of typical tin-base bearing alloys at temperatures up to 175° C. and to try the effects of additions of lead and cadmium. It was found that as the temperature rises the maximum stress and yield point fall fairly uniformly, while elongation and reduction in area increase. Cadmium markedly improves tensile strength of the alloys when cold, but is of little benefit when they are hot, and the effect of 4% of lead, although slightly beneficial when cold, is reversed at the higher temperatures.

Copies of the above publications may be obtained free of charge from the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C. 2.

Wire-Drawing

Many interesting problems encountered in wire-drawing were discussed by Prof. F. C. Thompson, M.Sc., D.Met., at a recent meeting of the Midland Metallurgical Society, which are presented in this article.

As a result of the fact that the mathematical treatment of plastic deformation is still in its infancy, it has not, so far, been found possible to treat the wire-drawing process on rigidly mathematical lines. The attempt of Sachs, interesting as it is, leads to one conclusion which can be shown to be inaccurate. This work suggests that the power required to draw wire is proportional to the logarithm of the ratio of the original and final areas. It can be shown experimentally that this is not so. If the subject is dealt with in a simpler manner, from the point of view of the dimensions of the factors involved, it can be shown that the power is directly proportional to the elastic limit of the material to be drawn, to the speed of drawing, and a factor which depends upon the area. If the relationship between the pull and the speed of drawing for an 18% nickel-silver is shown however, it will be seen that at very low speeds the prediction that the pull is independent of the speed is completely falsified, the tension increasing markedly as the speed of drawing is raised. If higher speeds are used then the tension needed to effect a given reduction for a given material is quite independent of the speed at which the wire is drawn. Practical confirmation of this has been obtained both on fine wire and thick rods for bolts, at any rate at speeds up to well over 1,000 ft. per min. Comparatively low speeds of drawing of the order of 300 ft. per min. are, however, still used in the drawing of high-carbon steel wire for ropes. Justification for this is claimed on the ground that age-embrittlement of high-carbon steel wire increases as the speed of drawing is raised. An investigation on this point was carried out on medium- and high-carbon steel drawn at rates varying from about 30 ft. to 600 ft. per min. So far as change in the tensile strength is concerned, no difference whatever could be detected in the ageing characteristics of the slowly and quickly drawn wire.

Brown and Giraud, among others, have shown that the pull required is a linear function of the reduction of area, but both sets of measurements were made at low speeds and on somewhat similar materials. Further investigation has shown that for 70—30 brass, nickel, cupro-nickel and nickel-silver, the same relationship obtains up to reductions of 50% to 60%. In the case of steels, the reduction of area/tension curves remains linear only until up to a reduction of about 30%, the pull required for larger reductions being less than would be expected. How far this deviation in the case of steel is due to the increased heat generated, and the rise of temperature of both wire and lubricant, cannot at present be determined; but it is clear that for non-ferrous materials over a very wide range of reduction, and for steels up to 30%, the tension increases linearly with the reduction of area.

The importance of the angle and contour of the die cannot need any emphasis. Using carbide dies for non-ferrous metals, the minimum tension is required with a semi-angle of about 5½° to 6°. Smaller angles lead to rapidly increased tension. This result has been confirmed for wide ranges of reduction of area on wide ranges of non-ferrous metals with good and bad lubricants, for materials both in the annealed and cold-drawn condition. The results for steel are much less simple, a succession of maximum and minimum values following each other over the whole extent of the curve. It is impossible to offer any explanation of this, but the fluctuations have a very real existence.

The extensive use of the "radial-taper" bearing, especially for non-ferrous wires, makes it desirable to compare this contour with the plain conical dies. In all cases, both for ferrous and for non-ferrous metals, the power consumption with the radial bearing exceeds that required for the plain, conical die. The difference in the power consumption decreases however as the reduction of area becomes greater, and as the metal drawn becomes harder. In the case of Post Office bronze, the power consumed in effecting a 20% reduction through a radial-taper die was 39% higher than that through a die of straight taper of 6° semi-angle. In the case of Monel metal, the difference for the same reduction of area had fallen to 16%, for a reduction of 35% had been reduced to about 10%. In every case examined, with good and bad lubricants, the pull necessary to effect a given reduction was less with a carbide die than with a steel die of the same contour. If compared with diamond dies, the pull required with the latter is less than with the carbide die. For an 80/20 cupro-nickel, 0·044 in. dia., the pull required to effect a 20% reduction of area was 44·5 lb. with a carbide die, as compared with 35 lb. in the diamond die, the same "Germ-oil" lubricant being used in each case.

Although a considerable amount of work has been done on lubrication, the number of fundamental facts which have been definitely established is small. Lubrication in this process is still largely empirical, though one of the most important of all the facts which have emerged is that the lubrication is in all probability of the "boundary" type. One material has, however, given interesting and unexpected results. At room temperature water is a particularly bad "lubricant." As the temperature is raised its efficiency improves considerably, and at temperatures just below its boiling point is almost as high as that of a really good soap. Further, the surface of the wire drawn with nearly boiling water is very good and suitable for subsequent treatments by processes such as enamelling. The importance of adequately anchoring the lubricant to the surface of the wire will, in view of the boundary nature of the film, be readily appreciated. It is now generally accepted that the value of the "water-coat" in the drawing of steel lies in its ability to absorb and retain a stable film of the soap. The extension of the use of such a film to non-ferrous wires is a possibility which is well worth exploring.

One aspect of the use of soap as a wire-drawing lubricant, which is of practical importance, is the dermatitis to which it may give rise. Some soaps are particularly liable to cause trouble of this kind, and there are good grounds for the belief that soaps made from fat charges, including a large proportion of cocoanut or palm-kernel oils, react on the skins of those liable to this complaint. The trouble may be eliminated if, prior to work, the hands are well rubbed with a mixture of unsalted lard and 5% boric acid.

Although rotating dies have been employed to a limited extent, the much simpler process of rotating the wire itself during the drawing is more generally employed. At low speeds of drawing there is a remarkable reduction in the tension required to draw the wire if the die is rotated; in the case of a 17% nickel-silver the pull being reduced from 73 lb., with a stationary die, to 27 lb. with one rotated at 160 r.p.m. What holds good for low speeds of drawing will not, however, probably apply at those speeds which are commercially used. As the speed of drawing is increased the tension required with the rotating die increases rapidly, and above a certain speed actually becomes greater than that for a stationary die. So far as the few tests go, which have been made on the mechanical properties of wires drawn through stationary and rotating dies, no difference has so far been detected. When a backward pull is applied

to wire being drawn through a die, the direct tension required increases in direct proportion to, but at a lower rate than, the back pull. The resultant force acting on the die, however, decreases somewhat rapidly as the backward pull is raised, to such an extent that in some cases it is quite easy to push the die along the wire by hand, even when a reduction of area of 20% or more is being effected. A rotary motion of the die at the same time greatly facilitated the operation. There is some possibility that in the case of steel wire the ductility of the material may be distinctly less when a backward pull is deliberately applied than when the same material is drawn in a more normal manner.

The Non-Ferrous Metal Smelting and Refining Industries of Canada

THE rapid development in recent years in metal mining operations of every description has brought in its train an equally rapid expansion in the facilities available for treating the complex ores from which metals are recovered in Canada. During the first six months of this year, her mining industry has enjoyed an exceptionally progressive period, aided by the relatively high level in the prices of copper, lead, and zinc, and by the heavy demand for metals in British and foreign markets.

The production of minerals in Canada last year reached a total of $361,919,372, as compared with $312,344,457 in 1935. Of last year's total, metals accounted for $259,425,194. During the first half of 1937, there has occurred a further rapid expansion, as the production of metals during the half-year has risen in value from $121,847,885 to $164,211,056, partly, of course, owing to the increased prices, but very largely as the result of the greater volume of metals turned out.

Refined products resulting from operations in Canadian metallurgical works were valued last year at $229,737,420, an increase of 23·3%, as compared with the 1935 total of $186,245,658. These products included gold, silver, copper, lead, zinc, aluminium, cobalt, cadmium, selenium, tellurium, radium salts, uranium compounds, bismuth and sulphur; other end products of individual plants or companies included copper-nickel matte, cobalt and nickel salts and oxides, arsenious oxide, sulphur in sulphuric acid, platinum metals residues, and blister and anode copper.

The estimated cost of ores, concentrates, and other material treated during 1936 was $137,857,432; fuels and purchased electricity consumed totalled $12,613,763; chemicals and various other process supplies used amounted to $7,989,580, and the net value of production (or value added by processing) was estimated at $71,276,645, or an increase of 19·9% above that of the preceding year.

Canada has now achieved a leading position in many branches of metal production, ranking fourth last year in respect of refined copper, and third so far as mined and smelted copper is concerned. Canada was the fourth largest world producer of lead bullion last year, and the third producer of metallic zinc, although second in world importance as a producer of the metal from domestic ores.

Production of Copper

During the first six months of this year, Canada produced 243,919,406 lb. of copper, valued at $34,377,884, an increase during the period of 18% in volume and of 89% in quantity. Gains were recorded in every province. Nova Scotia accounted for a small output in ores exported from the Sterling mine. Quebec production consisted of blister copper made at Noranda, and copper in exports from the Aldermac and the Consolidated Copper and Sulphur Co. Ontario's output came almost entirely from the nickel-copper ores of Sudbury; Manitoba's and Saskatchewan's from the Hudson Bay Mining and Smelting Co. British Columbia's production consisted of exports from the Britannia, exports of a copper matte by the Consolidated Mining and Smelting Co., and other minor shipments. Owing to the higher prices now prevailing, the Granby Consolidated Mining, Smelting and Power Co., Ltd., have reopened their Copper Mountain property and began shipping in July. The Sherritt-Gordon in Manitoba, after a shut-down of just over five years, resumed production about August 1.

Nickel Production

Nickel production during the same period totalled 111,610,392 lb., valued at $29,218,283, an increase of 34% in quantity and of 36% in value, as compared with the corresponding figures for 1936. Output included the refined nickel made in Canada, nickel in matte exported, and in salts and oxides sold. New activities in nickel mining in Ontario consisted of development work at the Denison Nickel Mines, Ltd.; the reorganisation of the Cuniptau, now known as the Ontario Nickel Mines, Ltd.; and the organisation of the Kenora Nickel Mines by the Coniagas Mines, Ltd., to develop its Empire Lake nickel property. The B.C. Nickel Mines, Ltd., reported shipments of nickel-copper ores and concentrates to Japan for experimental purposes. Production, at a daily capacity of 250 to 500 tons, is expected to begin shortly; the decision is dependent on negotiations at present in progress with Japanese interests.

Lead Production

Lead output during the first half of the year totalled 199,204,363 lb., valued at $11,667,399, a gain of 10% in quantity and of 83% in value. The mines of British Columbia accounted for 99% of the total output; exports of lead in concentrates from the Yukon were higher; the Sterling mine in Nova Scotia reported shipments of lead concentrates. No production was recorded for Quebec.

Zinc Production

Zinc production amounted to 170,535,713 lb., valued at $9,348,768, an increase of 8% in quantity, but of 79% in value. British Columbia's production totalled 135,651,801 lb., as compared with 122,109,829 lb. during the first half of last year. Manitoba and Saskatchewan combined accounted for 31,805,540 lb., as compared with 32,038,740 lb. in the first half of 1936. Shipments from the Sterling mine in Nova Scotia made up the remainder.

Rare Metals

Canada is now coming rapidly into the market for many of the minor metals. During the first half of 1937, for instance, the production of cadmium, which is obtained in the refining of zinc, increased by 11% in quantity, but of 60% in value to a total of 373,014 lb., valued at $559,522. Selenium and tellurium are recovered in the refining of copper and during the first six months in question there was a production of 165,994 lb. of selenium, valued at $285,509, in addition to 46,033 lb. of tellurium, worth $79,177. Radium and uranium production is also proceedingly actively.

Growth of Metal Consumption in the U.S.S.R.

BY A SPECIAL CORRESPONDENT

Progress achieved by the Soviet Union in metal production in the past eight years.

THE basis of the national economy of the U.S.S.R. was radically changed during the period of the first and second five-year plans. The reconstruction of the entire economic system on modern lines made necessary the speeding-up of the production of base metals. This was successfully accomplished during the period of the second five-year plan. Ferrous metallurgy, which at the beginning of the plan was somewhat backward, has to-day become a leading Soviet industry.

The production of pig iron in the U.S.S.R. in 1936, as compared with 1932, had increased 2·3 times, the production of steel 2·7 times, and rolled metal 2·9 times. The increased production of ferrous metals during the second five-year plan made it possible to expand other industries at a great rate, particularly the metal-consuming industries. To-day the U.S.S.R. holds second world place, and first European place in ferrous metal consumption, as is shown by the following figures :—

VISIBLE CONSUMPTION OF FERROUS METALS, 1929-1936 IN 1,000 TONS IN TERMS OF STEEL.*

	1929.	1932.	1935.	1936.
U.S.S.R.	6,145†	8,976	15,855	18,716
U.S.A.	62,993	15,279	37,241	—
Germany	15,322	5,244	15,656‡	—
Great Britain	12,496	7,624	11,688	—
France	9,829	5,867	5,618§	—

* The visible consumption of ferrous metals has been estimated on the basis of adding the foreign trade balance in ferrous metals to the annual production of cast iron and steel. The figures for the U.S.A., Germany, Great Britain, and France have been taken from *Stahl und Eisen* No. 50, 1936, p. 1,514. The foreign trade balance of rolled metal has been converted into terms of steel at the coefficient 1·25.

† The figures for the U.S.S.R. are for the last quarter of 1928 and 1929.

‡ From March, 1935, including the Saar.

§ From March, 1935, without the Saar.

The visible consumption of ferrous metals in the U.S.S.R. is seen to have increased from 6,145,000 tons in 1928-29 to 18,716,000 tons in 1936. The consumption of these metals in the whole of Russia in 1913 was 5,683,800 tons. Thus, the annual consumption of ferrous metals in the U.S.S.R. to-day has more than trebled, as compared with 1913. At the inauguration of the first five-year plan the consumption of ferrous metals in the U.S.S.R. was 2½ times less than in Germany, half that of Great Britain, and 1½ times less than that of France.

Important changes took place during the second five-year plan in the proportion of ferrous metals consumed by the different branches of industry. Metallurgy in pre-war Russia was developed mainly in the interests of the railways, small municipal requirements, and the needs of agriculture and housing. The consumption of the engineering industries was negligible, the major part of machinery then used in Russia being imported. During the period of the first and second five-year plans the U.S.S.R. created a powerful engineering industry, which has become a great consumer of metals. The total consumption of rolled metals by all the Soviet metal consuming industries in the period 1928-29 to 1936 was as follows :—

1928-29	1,600,000 tons of rolled metals
1932	2,619,000 „ „
1935	4,893,000 „ „
1936	6,060,000 „ „

During the years under review great expansion took place in the automobile and tractor industry, the transport and agricultural machinery industries, the machine-tool industry, the heavy engineering industries, etc. The growth in the consumption of rolled metal by these industries is illustrated in the following table :—

CONSUMPTION OF ROLLED METAL BY PRINCIPAL MACHINE-BUILDING INDUSTRIES IN U.S.S.R. (in 1,000 tons).

	1929/30.	1932.	1936.	1936 Percentage, Compared to 1929-30.
Transport equipment	298	392	1,253	420·5
Automobile and tractor	89	285	948	1,065·2
Agricultural machinery	275*	252	564	205·8
Heavy engineering	126	251	445	252·8
Power machinery	65	126	183	281·5

* For 1928-29.

The consumption of rolled metal in 1936 showed an increase over 1929-30 of 4·2 times for the transport equipment industry, 10·6 times for the automobile and tractor industry, more than twofold for the agricultural machinery industry, 2½ times for the heavy engineering industry, and 2.8 times for the power machinery industry.

It may be mentioned in passing that the volume of agricultural machinery produced in the U.S.S.R. to-day has already surpassed that of the United States, and the volume of transport equipment produced is almost on a level with that of the United States.

The figures for rolled metal consumption given for the transport equipment industry are by no means a complete indication of the latter's consumption of ferrous metals. In addition to rolling stock, this industry uses a large quantity of rails and rail joints for the construction of new railways and the reconstruction of old ones. Reconstruction of railway tracks in the Soviet Union during the period of the second five-year plan has been carried out on a big scale. The total amount of rolled metal consumed for all railway requirements, including rolling stock and supplies for superstructure of the permanent way, averaged 940,000 tons a year during the first five-year plan (1929-32), and was 975,800 tons in 1933, 2,517,400 tons in 1935, and 3,463,000 tons in 1936 (incomplete figures).

The proportional changes in the consumption of metals by the different industries during the first and second five-year plans have been attended by important changes in the grades and quality of metals consumed. The development of engineering industries manufacturing machine-tool and chemical plant necessitated an increased supply of ferrous metals, also the production of tougher and more durable metals, metals with greater resistance to corrosion, to high temperatures, etc. The production of high-grade metals had to be developed quickly, with the result that during the last eight years the output of high-grade rolled metal rose by nearly twenty-fivefold. From 90,400 tons in 1927-28 the output increased to 682,600 tons in 1932, 1,671,500 tons in 1935, and 2,200,000 tons in 1936, while the estimated output in 1937 is 2,704,000 tons. It is noteworthy that the original objective of the second five-year plan was for an output of quality rolled metal in 1937 of 2,000,000 tons.

Intensive work was also carried out in mastering the production of new types of quality steel and developing the production of high-grade alloyed metals for use in the manufacture of important machine parts and instruments. The production of high-speed, ball-bearing, heat-resistant, acid-resistant, stainless and magnet steels, as well as dynamo and transformer iron, has been greatly developed. The total output of alloyed steel in the U.S.S.R. amounted to 9,600 tons in 1927-28, 150,400 tons in 1932, and 371,200 tons in 1935.

At the same time, new demands were made for sections of various shapes and sizes. The growth of the automobile and tractor industry meant an increased demand for supplies of sheet and sections, including a variety of special sections. The development of the power engineering industry entailed new demands for special types of sheet metal—dynamo and transformer iron. The growth of the machine-tool engineering industry called for new shapes of tool steel.

There has been a considerable expansion also in the range of sheet and plate. The extensive development of locomotive and rolling-stock output, shipbuilding, automobile and tractor engineering, the production of electrical power equipment, the development of petroleum, chemical and canned goods industries, have given rise to a great

demand for different types to meet individual requirements. This is shown in the following production figures :—

PRODUCTION OF SHEET IRON (IN 1,000 TONS).

	1928/29.	1932.	1936.	1937 Plan.
Total output of sheet iron	426·8	513·9	1,500·2	1,794·0
Which includes :—				
Thin sheets, 1–3 mm. thick	125·6	171·9	303·0	469·0
Boiler and furnace plates	20·2	12·9	65·5	104·8
Corrugated sheets	2·0	1·5	7·5	11·0
Frame plates	2·7	4·2	22·3	28·6
Corrugated sheets	6·6	—	80·5	181·1

The successful mastery of the processes of production of the new types of metal required in modern engineering made possible a sharp reduction of imports of these metals from other countries during the period of the second five-year plan. During the first five-year plan, when the Soviet Union was rapidly developing her engineering industries and the metallurgical industry had not yet been reconstructed, ferrous metals were imported in large quantities. Under the second five-year plan the requirements in metals were covered almost entirely by home production. Such metals as were imported consisted mainly of rolled metals and ferro-alloys. The following figures show the growth of consumption of rolled metal and ferro-alloys in the U.S.S.R. during the period of the second five-year plan, and the attendant decline in imports, which constitute but a negligible proportion of the total quantity of metals consumed :—

CONSUMPTION AND IMPORT OF ROLLED METAL AND FERRO-ALLOYS IN U.S.S.R. DURING 1928-29 TO 1936 (IN 1,000 TONS).

	1928-29.	1932.	1936.
Rolled Metal—			
Total consumption	4,030·3	5,193·0	11,773·0
Imports	243·2	893·7	214·9
Proportion of imports to consumption	6%	17·2%	1·8%
Ferro-Alloys—			
Total consumption	10·4	28·6	294·5
Imports	9·9	12·9	2·6
Proportion of imports to consumption	95·2%	45·1%	0·9%

This brief summary of the progress achieved by the Soviet Union in metal production and consumption indicates the extent of the industrial progress this country has made during the last eight years.

Inclusions in Alloy Steels

A method of production control is discussed, which, when the constitution and properties of the inclusions are known, will facilitate the reduction of their number, control their shape, type and distribution.

NON-METALLIC inclusions in steel may be produced as (1) products of deoxidation, which may be either oxides or combinations such as silicates, aluminates, etc. ; (2) slag or refractory particles ; or (3) inclusions introduced in the raw materials and deoxidising agents used. Ordinary inclusions in steel are considered as objectionable, yet their presence in minute or sub-microscopic size probably has an important relationship to grain size and abnormality effects, hardenability, impact strength, etc. The nature of inclusions has also an important bearing on their physical properties, as those of high melting point retain their shape during rolling, while inclusions of low melting point are elongated, and in this condition their detrimental effects are far more serious than the same amount of material in isolated or compact form. The degree of elongation depends upon the mineralogical composition of the inclusion phases.

An accurate knowledge of the nature and composition of inclusions is therefore extremely valuable in maintaining the desired close control of the properties of alloy steel, and the usual methods of inclusion study, metallographic examination and chemical analysis of the oxides in the steel, are insufficient in themselves to determine definitely the nature of the inclusion phases. The importance of having this information has therefore led to the development of a method of studying the problem utilising and combining metallographic, chemical, petrographic, and X-ray methods of examination. This improved method of studying inclusion in alloy steels is described by W. A. Hare and G. Soler in a recent issue of Metals and Alloys.*

Metallographic examination alone has the great advantage of speed and observation *in situ*, but may lead to erroneous conclusions as to the chemical nature of the inclusions, as well as being unsatisfactory as a whole, due to segregation of the non-metallic particles. Chemical analysis avoids the effect of segregation to a large extent and permits of accurate qualitative and quantitative analyses being made, but when used alone it does not show up the combinations or phases in which the oxides exist or their manner of distribution in the steel. Petrographic study of inclusions properly isolated by chemical means enables accurate determinations to be made of the actual phases or combinations of oxides representing each type of non-metallic inclusion present. In general petrographical examination comprises the indentification of a non-metallic phase by the microscopic determination of its refractive index and other properties. Those inclusions difficult to study by such a method due to opacity or solid solution phase may be checked by means of X-ray diffraction powder photographs. The new method of study consists, in general, of separation from a steel sample by suitable chemical means of the inclusion material free from contamination, and the determination of its total composition. A portion of the separated material is then studied petrographically to determine the phases composing the individual inclusions, and the information thus obtained is checked by metallographic examination, noting the inclusion distribution within the steel itself.

Samples for examination were either entire cross section slices of rolled bars or slice sections from the centre of ingots cut with a saw and filed with a clean file, as previous work had indicated that drilling was unsatisfactory. Fine drillings always gave a much higher oxide content than coarse drillings. Various electrolytes were experimented with for the separation of the inclusions from the steel including Scott's solution, Fitter's solution, copper sulphate, various buffered solutions with tartrates and citrates present, and potassium iodide solution, and the first was found most suitable for alloy steels. This method employs the electrolytic decomposition of the sample as the anode in an electrolyte of magnesium iodide. It was adopted with certain modifications, which included the elimination of oxidation of iron salts by air during electrolysis by passing a neutral atmosphere over the sample and electrolyte, and by modifying the washing technique after electrolysis to eliminate attack on the inclusions during washing.

In the modified method the electrolyte was composed of a 7% solution of magnesium iodide to which 3 grammes of iodine per litre was added before each run. This was contained in a glass cell with a ground glass lid, having a ½ in. bakelite spacer placed between the lid and the cell to allow for the passage of several tubes for inlet and outlet of neutral gas such as nitrogen, and for electrode wires. A sample of about 30 to 60 grammes of steel was hung within a beaker, whose bottom had been cut off and replaced by a sheet of hard filter paper held in place by a rubber band,

**Metals and Alloys*, 1937, Vol. 8, No. 6, pp. 169-172.

and having a sheet of quantitative filter paper folded conically and placed beneath the sample to catch any particles, which might fall during the electrolysis. The level of the electrolyte was such as nearly to cover the sample, which was the anode of the cell, and a cylinder of copper gauge in the outer cell was the cathode. The voltage used was held constant at 2 or 3 volts, and about two or three days was required for electrolysis to be complete, and electrolysis was completed in the absence of oxygen and no iron salts or oxide were precipitated.

After electrolysis was complete the residue was removed, filtered, and thoroughly washed, and any non-electrolised sample weighed and subtracted from the weight of the original sample. The residue was then treated with 50 c.c. of 5% sodium tartrate solution, filtered, washed, and treated twice with an alcoholic solution of iodine to decompose the carbide, the amount of iodine (2 to 5 grammes) being varied with the carbide present, but an excess always being necessary. After treatment, the residue was washed free from iodine with potassium iodide solution, and washed with sodium tartrate and sodium carbonate solutions, before being ignited and analysed for silica, alumina, ferrous oxide, manganese oxide, etc. A sample was treated in the same way for the petrographic phase determination, and the ignited residue, which was free from appreciable contamination was examined.

This method of studying inclusions has been carried out on a large number of steels of different specifications and appears to be entirely applicable to all types of alloy steels, except those containing both chromium and carbon in more than moderate percentages. All plain carbon steels, nickel steels, low molybdenum steels, and low chromium steels may be tested for inclusions by this method. In the case of steels where carbon and chromium are present together to such an extent that there is contamination of the residue with insoluble chromium carbide the method is not suitable, and it is necessary to resort to a dry decomposition in chlorine gas. The accuracy of the method is very satisfactory and oxides present may be checked within very small limits.

As regards the application of the method to production control, when the constitution and properties of the inclusions are known, it is possible to apply the information obtained to manufacturing process in an endeavour to reduce the total number of inclusions, control their type, shape, and distribution, and study the effect of these changes on the various physical properties of the steels.

Fusible Alloys Containing Tin

Many interesting and surprising applications of fusible alloys are described by E. J. Daniels, M.Sc., in a monograph of 22 pages bearing the above title. Ten pages are devoted to considering the bearing of composition upon the melting point, and the structure and physical properties of the fusible alloys, another ten pages describe their applications, and the references to published literature on the subject occupy the two other pages. It is shown that Wood's metal, Lipowitz's alloy and other well-known compositions are extremely close approximations to the eutectic mixtures of phases consisting of either pure metals, solid solutions of one metal in another, or intermetallic compounds. The microstructure is important, since the strength and behaviour of the alloys depends on it. It is important to cast the alloys under controlled conditions to get dependable results in regard to plasticity and creep. The solidification of many of these alloys is accompanied by expansion instead of contraction because they contain bismuth or antimony. The problems of corrosion of fusible alloys, and methods of avoiding troubles due to this cause, are discussed.

Amongst the applications given are sprinkler plugs, boiler plugs, fusible links, seals for glass apparatus, patterns for moulding and electroplating, tube bending, tempering baths and die-mounting.

Light Metals for Commercial Vehicle Body Construction

Some while ago, Messrs. Reynolds Tube Co. Ltd.—in order to demonstrate the advantages gained by the use of RR56 and RR66 light alloys in commercial vehicle construction—produced special sections for this purpose for use in conjunction with sheet, so designed as to produce a body with the greatest rigidity possible coupled with lightness, which in the particular case in question resulted in saving the annual tax, which, coupled with the economy in running, prompted the Company to order a further body for a new chassis. The work in both cases was carried out by Messrs. Jensen Motors Ltd., West Bromwich.

This body is of somewhat different construction to the original one in so far that it is lower, and the introduction of wheel boxes are so arranged that they are independent of the drop sides, and therefore do not break up the symmetry of the sides.

Complete motor vehicle body in aluminium.

The internal measurements of this body, which is shown in the accompanying photographs, are 14 ft. 6 in. long, 6 ft. 8 in. wide and 15 in. deep. The flooring is of 10 gauge RR66 sheet and the sides and tailboard of 12 gauge. The main cross members are of "I" section in RR.56, as also are the main angles which run all round the body floor to the end posts to which the drop sides are secured. Special sections were employed for the vertical stiffening channels on the sides which also form the hinges, and a special section was also employed to go the whole way round the sides and tail board which forms a very neat finish and at the same time gives very great strength.

RR66 rivets were used throughout in the construction and wherever bolts were employed for fastening to the chassis, these were of cadmium-plated steel, for it is important to remember that dissimilar metals such as aluminium alloy and steel in close contact will eventually become corroded, due to electrolytic action, especially in the presence of moisture. Where the cross members come in contact with the chassis, necessary protection is afforded by the insertion of fabric soaked in tungoil varnish. It must be pointed out that such attention to details are essential if light alloy materials are to be employed successfully in body construction.

The total weight of the body, which, as can be seen, can be carried by two men, is 4 cwt.

Mechanical Properties of some Tin Bronzes

The proportion of tin used in bronzes intended for cold-working may amount to 7% or 8% usually, but recent work suggests that there are advantages attaching to the use of as much as 14% of tin. Dr.-Ing H. Lepp, of the Compagnie Générale d'Electro-Metallurgie of Paris, has found greatly improved elongation and malleability in bronzes of this kind which have been properly degassed. His results are summarised in a new Technical Publication, Series D, Number 3, just issued by the International Tin Research and Development Council, from whom copies may be obtained free of charge.

International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C. 2.

Desulphurising and Refining Blast-Furnace Iron with Sodium Carbonate

A new principle has been developed for the manufacture of pig iron in the blast furnace under conditions which give the maximum rate of production with low coke consumption by which desulphurising is effected when the metal leaves the furnace.

THE recent development of the use of sodium carbonate as a flux for the treatment of molten metals, particularly cast iron, has provided a valuable means of controlling quality and composition, and the process has won for itself an acknowledged place in various branches of the foundry industry. In the manufacture of refined pig iron and converter steel castings, where a low-sulphur content is essential, sodium carbonate is now regarded as essential. In the production of various types of engineering castings where fine machined surfaces and perfect soundness are called for, and a close grain to resist the corrosive action of liquors and the effects of heat, its refining action plays an important part.

Sodium carbonate has also been of vital importance in recent developments in the steel industry. The use of the aluminous ores of Northamptonshire for making low-silicon basic iron was regarded as impracticable until certain radical changes were made in blast-furnace technique. This type of metal is now being produced successfully on a large scale in Northamptonshire.

There are two principal methods of treating cast iron with sodium carbonate—the most important being to tap the metal on to granular sodium carbonate in a ladle or receiver; and the second, used with cupola melting, the addition of fused sodium-carbonate blocks to the cupola charge. In applying the former of these two methods, it is often necessary to thicken the fluid slag so that it can be moved easily from the melt. This is done by the addition of a special grade of limestone.

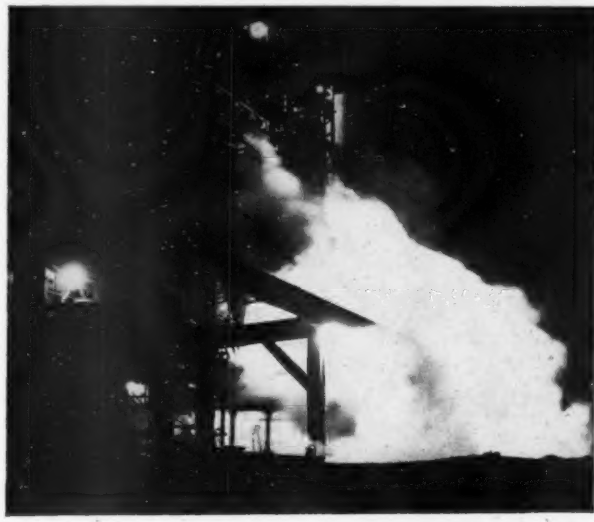
Desulphurising Basic Blast-Furnace Iron

Owing to the difficulty and cost of removing sulphur in basic open-hearth furnaces and converters, sodium carbonate is widely used for desulphurising basic iron for both open-hearth and Bessemer steel, as well as other grades of blast-furnace metal. The treatment can be applied to the ladle between the blast furnace and the mixer or pig bed, between the mixer and the open-hearth furnace or converter, or between the blast furnace and the steel furnace when no mixer is used. The method usually adopted is to begin tapping from the blast furnace or mixer into the ladle, and then to throw in granular sodium carbonate. The proportion of sodium carbonate required varies from ½% to 2% or more of the weight of iron to be treated, depending upon the amount of sulphur to be removed.

Acid Process for Blast Furnaces

Recently there has been developed a new principle for the manufacture of pig iron in the blast furnace under conditions which give the maximum rate of production, and the lowest coke consumption per ton of pig iron made. In this process the blast furnace is considered to be essentially a plant for producing iron, but not for refining it. The sulphur content of the iron is adjusted when the metal leaves the blast furnace.

The process was first operated at the Corby Works of Messrs. Stewarts and Lloyds, Ltd., where its inventors, Messrs. H. A. Brassert and Co., Ltd., were faced with the problem of producing low-silicon basic iron from Northamptonshire ore high in alumina content. The difficulty was mainly due to the refractory nature of the blast-furnace slags produced, and the consequent occurrence of scaffolding, when burdening the furnace on conventional lines. When this problem was solved it was realised that the same principles could be applied to other types of iron ore, with corresponding economic advantages.



In order to attain these results the burden of the blast furnace and the addition of flux are so regulated that a slag of the lowest possible melting point and visoscity is formed; for such conditions the ratio of lime to silica in the slag is approximately unity. This is a radical departure from the normal practice, where a much higher proportion of lime is added to the burden giving a ratio of lime to silica in the slag of 1·4 to 1·6. This ratio has been maintained in the past largely with the object of desulphurising the iron in the blast furnace. The new principle separates the two operations of iron production and desulphurisation, the latter being carried out after the iron has been tapped from the furnace.

The method of desulphurising has already been mentioned, but it is interesting to note that where large quantities of iron have to be treated, and in districts which are favourably situated for the supply of limestone and fluorspar, it has been found that mixtures of these minerals with sodium carbonate may prove more economical than plain sodium carbonate. The best results have been obtained by the use of a mixture of one part of sodium carbonate with three parts of limestone and one part of fluorspar. The latter gives the slag the necessary fluidity. The volume of slag, when the mixture is employed, is approximately two-and-a-half times that of a sodium carbonate slag; but in the case of large quantities of slag, contained in blast-furnace ladles, the additional cooling action of the extra slag volume is of no importance.

The process is so flexible, however, both as regards the stages at which desulphurisation may be carried out, and the quantities of sulphur which may be removed, that it is easy to treat iron of any sulphur content, and reduce it to any desired figure to meet even the most exacting specification.

This new development gives very marked economies in operation. It has been found, in one case, that there is an increase of about 20% in the rate of production, and a saving of 15% or more in the coke consumption per ton of

iron. Some of the factors contributing to these savings are:

(a) The low-melting point slag melts high up in the furnace, leaving the bosh free from danger of scaffolding and contributing to regular operation of the furnace.

(b) The smaller additions of limestone to the burden result in a lower slag volume and lower heat requirements.

(c) Coke is the only solid material in the combustion zone. The air blast has therefore a freer passage, giving more rapid combustion of the coke at a lower blast pressure. As the rate of production depends on the rate of coke combustion, this increases output.

(d) There is no need to add manganese ore to the burden to increase the manganese content of the iron, and remove sulphur as manganese sulphide.

The fact that desulphurisation in the furnace may be entirely ignored, and that percentages of sulphur as high as 0·6% can be satisfactorily reduced at subsequent stages, opens up to the iron producer numerous sources of ore and coke which have previously been regarded as unsuitable on account of their high content of sulphur.

The iron produced is of higher quality than that made by the conventional methods of burdening, largely on account of the greater activity of the very fluid blast-furnace slag. The treatment with sodium carbonate has a further powerful cleansing action, for in addition to the chemical reactions which reduce the sulphur content, the turbulence caused by the rapid evolution of carbon-dioxide gas, together with the rising of the fluid-slag particles, carries to the surface all traces of unreduced oxides and other non-metallic inclusions.

The information contained in this article has been extracted from a valuable book on " Sodium Carbonate for Metal Refining," recently published by Imperial Chemical Industries, Ltd., Millbank, London, S.W. 1, and it is noteworthy that an agreement has been concluded between this Company and Messrs. H. A. Brassert and Co., Ltd. which has for its object the joint development of the Brassert process. The technical resources of both companies are available to firms wishing to operate their blast furnaces according to the new principle.

Corrosion-Resistant Metals for Textile Equipment

WHILST wood, steel, cast iron, copper and ebonite were the normal materials used in the construction of textile equipment up to the close of the war years, they have now been superseded in a large measure in wet-processing operations by modern alloys, said Mr. N. C. Marples, in a paper read before a recent meeting of the Textile Institute at Manchester. The author pointed out that textile engineers are familiar with the difficulties due to corrosion in dyeing and bleaching, and he referred to the advantages of two modern alloys—Monel and Inconel—for certain applications in textile wet processing. Monel, an alloy containing approximately two-thirds nickel and one-third copper, is already widely used in the textile industry, particularly for dyevats and linings, winches and heating coils.

Reviewing the possibilities of this material in respect of the wide variety of dye-stuffs, Mr. Marples also referred to the use of Monel for equipment used in bleaching by means of hypochlorites and hydrogen peroxide.

So far as textile work is concerned, he remarked, Inconel offers particular promise for the construction of wool-dyeing equipment, also for equipment in which dyeing is by means of developed colours employing a nitrous-acid bath. Inconel is made up of approximately 80% nickel, 14% chromium and 6% iron. By virtue of its high-nickel content it is rust-proof, and has a good resistance to corrosion.

Whilst the corrosion-resistant properties of pure nickel are fully appreciated to-day, and the metal is widely employed for equipment in the process industries, the high first cost has, in the past, sometimes limited its use, particularly where considerations of pressure or rigidity have called for the use of plates of substantial thickness.

A recent development in this field is nickel-clad steel, which consists of a sheet of nickel inseparably bonded to a thicker sheet of steel, and its production, said the author, is a remarkable technical achievement. In general, it may be said that the thickness of the nickel is approximately 10% of the total thickness of the nickel-clad plate.

Nickel-clad steel can be simply and economically used to fabricate large pieces of equipment, and where joints have to be made the method of welding is such as to ensure that a continuous nickel surface is obtained. The material thus provides the textile engineer with a material particularly suited for the construction of heavy equipment. Peroxide bleaching kiers were instanced as an application where nickel-clad steel was being used to advantage.

Gold and Iridium Deposits Found in Tian-Shan Monntains

RICH deposits of gold and of iridium have recently been discovered by a party of Soviet gold prospectors on the Atbashinka River, in the central Tian-Shan Mountains. At present iridium is mined only in the Urals, in the Tuva Republic and in Australia. The find is of importance in view of the fact that the annual world output of this metal does not exceed 100 grammes.

New Standards Approved by the American Society for Testing Materials

ON the recommendation of a number of A.S.T.M. standing committees the Society's Committee on Standards, at a recent meeting, approved for publication as tentative a number of new specifications and tests, and also approved, for immediate incorporation revisions in certain tentative standards. Revisions in certain existing standards, specifications and tests were approved for publication as tentative.

Included in the list of new tentative standards is a new tentative specifications for carbon-molybdenum alloy steel pipe which cover a composition which was formerly incorporated in the Standard Specifications for Seamless Alloy-Steel Pipe for service from 750° to 1,000° F. Separate specifications were considered desirable because of the widespread use of the carbon-molybdenum type of seamless pipe, especially in the power industry. Because of its creep strength above 1,000° F., and its oxidation resistance properties, it was felt desirable to limit the temperature to 1,000° F. rather than 1,100° F., which was the limiting figure covered in the Standard. One heat-treatment is provided in the interest of ease of stocking. There is presented as information in an appendix a table of other thicknesses and signs agreed upon by the Prime Movers Committee of the Edison Electric Institute.

The existing standard specifications were revised by the incorporation of five new grades of steel, the specifications in their latest form giving requirements for 11 different grades. Extensive changes were approved in the Tentative Specifications for Alloy-Steel Bolting Materials for service from 750° to 1,100° F. This specification now includes chemical and physical properties for a number of grades of bolting steels in the body of the specification.

Specifications covering rolled wrought iron shapes and bars were approved for the first time on the recommendation of the Committee on Wrought Iron. Demand has arisen for these materials largely for use in railings and tubular structure of highway bridges. The shapes, sections and bars may be rolled from billets made from pig, puddled or processed wrought iron and are to be free from any admixture of iron scrap or steel. The tensile strength ranges varies from 46,000 to 48,000 lb. per sq. in., depending on the size of the material, with a minimum elongation in 8 in. from 20% to 25%.

Reviews of Current Literature

Metallurgist's Manual

Metallurgy involves the application of much scientific knowledge, including physics, chemistry, geology and engineering, and this book deals with these important factors suitable for the use of metallurgists throughout the world, metallurgical students in universities and technical schools, engineers and all others interested in any way in metals. Its scope is comprehensive, covering a sound method of making every assay or analysis commonly needed in mining and metallurgy; explaining how to conduct complete examinations of refractories and fuels; how to calculate furnace charges; a complete account of methods of measuring high temperatures; and essential information regarding the metallurgy, properties and uses of the chief industrial alloys.

The book contains a large amount of most useful information in tabular form, diagrams, formulæ and microphotographs. The latter are of alloys supplied by various firms and are representative of industrial types, making them of practical as well as academic value.

This tables mentioned include data regarding normal solutions; typical analyses of steels, irons, acid-resisting alloys, ferrous and non-ferrous alloys, electrical resistance alloys; the oxygen content of different bodies, etc. The calorific power of combustibles and the weight of oxygen and air necessary for combustion; specific heats, conversion tables and standard laboratory screens, are included.

A useful formula, and one which may be regarded as typical in the chapter devoted to various methods of steel analysis, is that which is part of the gravimetric method for determining the percentage of manganese . . . "The gravimetric method, though a slower process, gives greater accuracy, when properly carried out, than the volumetric method. Take 5 grams of the sample of steel, dissolve in 30 c.c. of hydrochloric acid plus 30 c.c. of water, and when solution is complete, add 5 c.c. of nitric acid to oxidise the iron. Dilute the solution to about 250 c.c. with hot water, cautiously add ammonia until the colour is deepened to dark red. Now add ammonium carbonate till the solution deepens to very deep red, indicating that the free acid is neutralised and the solution contains basic ferric chloride. Continue the addition of ammonium carbonate, a few drops at a time, until a permanent precipitate is just produced, clear this up with the smallest possible quantity of hydrochloric acid and heat to boiling. Now add 10 c.c. of ammonium acetate solution, bring to the boil, and make up to 500 c.c. at boiling temperature in graduated flask. Allow the precipitated basic acetate of iron to settle, and filter hot through large dry filter paper into a clean flask. Take 250 c.c. of the clear liquid in a graduated flask at boiling point and cool under the tap. Transfer to a wide mouthed flask, add 3 or 4 c.c. of bromine, shake round, add moderate excess of ammonia, heat to boiling and keep hot for several minutes to precipitate the oxide of manganese. Filter, wash with hot water, ignite, and weigh as Mn_3O_4, which contains 72·05% Mn. After allowing 5 c.c. for the volume to precipitate in half the solution, the percentage of manganese is found as follows:—

$$\text{Mm} = \frac{0\cdot7205 \times \text{weight obtained}}{\begin{array}{c}225\\ -\ 5\\ 500\end{array}} \times 100.$$

The chapters on metallography and pyrometry are specially commendable and are very well Illustrated. Another interesting and informative quotation we may make is that of the bromate method for determination of antimony in white bearing metals: "Take 1 grm. of the finely divided alloy. Digest in 50 to 60 c.c. of HCl, with the occasional addition of a few crystals of potassium chlorate ($KClO_3$) till all the metal is in solution. Boil to expel excess of chlorine. Add another 50 c.c. of HCl, 50 c.c. of water, and 5 grms. of sodium sulphite. Boil for twenty minutes or so to expel sulphur dioxide. Cool, add 50 c.c. of HCl, together with a few drops of methyl orange solution and titrate with the potassium bromate solution ($KBrO_3$) till the red colour disappears. When the reddish tint gets faint, add a few more drops of the methyl orange, and cautiously add the bromate, a drop at a time, well stirring, till the colour is discharged. Should the assay be overshot, add 50 c.c. of HCl, 5 grms. of Na_2SO_3, boil as above, cool, and repeat the titration with $KBrO^3$. The Number c.c. bromate solution $0\cdot006 \times 100 =$ percentage of Sb."

For the above method the authors recommend a standard solution of potassium bromate . . . "weigh out carefully on a good balance, 2·7852 grms. of pure $KBrO_3$ and make solution up to exactly a litre. If done carefully 1 c.c. = 0·006 Sb, and there is no necessity to check it against antimony."

These short extracts will help to show the value of this extremely useful and comprehensive manual.

By T. G. Bamford, M.Sc., A.I.C., and H. Harris, M.Sc., F.C.S. Published by Messrs. Chapman and Hall, 11, Henrietta Street, Covent Garden, London, W.C.2. Price 7/6 net.

Photomicrography with the Vickers' Projection Microscope

DETAILED instructions on the operation of the Vickers' Projection Microscope, and its many accessories, are given in this book, which also includes a chapter devoted to the theory of the microscope in general, and the application of that theory to the projection microscope in particular. It should not be thought that it is merely an instruction book, it covers much more ground than the type of book which generally comes under that heading, and its information should be of particular interest to our readers here and overseas.

The ten chapters include detailed description and instructions for assembly, electrical equipment and working instructions, selection of optical equipment, optical adjustments, preparation of specimens, and mechanical maintenance. The final chapter, although short, is certainly interesting—dealing with the application of the instrument in steel-works practice, this section including mention of the microscope for examination of foundry sands.

Published by Messrs. Cooke, Troughton and Simms, Ltd., York. Price 5s. net.

The Analysis of Non-ferrous Metal and Alloys

PRODUCED to meet a specific need, that of many works' chemists and general analysts who are now called upon to test for manufacturers, men who need definite instructions for tests on modern alloys, this book is essentially practical. It is the seventh of a series of industrial text-books edited by Dr. Percy Longmuir, which are designed to provide information in a concise, direct and condensed form, and this volume adequately fulfils these requirements.

The style of writing is very clear indeed, the same layout being used for each subject—first, the name of the element and the alloy in which it is contained, then a list of solutions required, and then the method of analysis, followed in many cases by helpful notes. These constitute the earlier chapters and the bulk of the book. Subsequent chapters deal with the procedure of analysis of raw materials and industrial alloys, the recommended methods being then designated by numerical references corresponding to those methods described in the earlier chapters. There are two appendices, one consisting of notes on the use and preservation of platinum apparatus, and the other of tables of atomic weights and factors of elements.

The authors are experienced through intimate contact with the estimations clearly defined, and it is noteworthy that the methods described are standard practice in the

research laboratory of a well-known works. This volume therefore will be of great service in all non-ferrous laboratories, while general and iron and steel-works' laboratories, which are frequently required to undertake the analysis of non-ferrous metals and alloys, will also find it useful. The book is especially suitable for the busy works chemist, while the student of metallurgy will find it of great service, since the methods given are essentially practical and enable accurate results being obtained in the minimum time.

By W. CARTWRIGHT, M.Sc., T. W. COLLIER and A. CHARLESWORTH. Published by Messrs. Charles Griffin and Co., Ltd., 42, Drury Lane, London, W.C. 2. Price 8s. net.

Vanadium Steels and Irons

THIS book gives a comprehensive review of the uses and many advantages of vanadium in ferrous metallurgy, the functions of vanadium both during manufacture and during service of the manufactured product being discussed very clearly. It is well illustrated throughout with diagrams and photomicrographs, and includes much useful tabular matter. It opens with a résumé of those principles with which the advantages of vanadium in steels are based, whether these additions be alone or in combination with other alloying elements.

Vanadium has a positive action in producing a very small grain size in steels, and in preventing grain growth upon heating; whilst its other main advantage lies in the effect of the vanadium rich carbides, their stability with increases of temperature, and the manner of their solution in, and their separation from, the more or less homogeneous steel matrix.

The fineness of structure in vanadium steels extends to the distribution of the carbide, and even in hyper eutectoid steels, the primary carbides affected are more uniformly distributed in smaller quantities. Its application in steels, even with such large amounts of free carbide as high-speed tool steels, and the very high-carbon, high-chromium steels for hot-work and abrasion resistance, is one of its pronounced advantages.

The considerable and consistent reduction in grain size and sub-division of structure within the grain is naturally reflected in many of the mechanical properties of the steel; chiefly in an increase in yield point, yield ratio, ductility and toughness.

The second chapter gives very useful information on plain-carbon steels for welding and for small case-hardened parts, and deals extensively with the extensive application of chrome-vanadium steels in U.S.A. This series consists of steels containing 0·80—1·10% Cr, 0·15—0·20% V, and 0·10—1·0% C. The usual method of fabrication of the low-carbon steels is by electric arc welding. Heavily coated Cr,V electrodes are used, and the welding is followed either by full annealing or by tempering for relief of stress. Much information is provided on the types of plates used for these purposes.

Full details are given on the use of vanadium steels for forgings in the heavy industries, and adequate mention is made of the more recently introduced Cr, Mo, V; Mn, Mo, V and Ni, Cr, Mo, V steels. It is interesting to note that all large American steelmakers and manufacturers of high-quality heavy forgings have used 0·05—0·20% V with full addition of Si and minimum Al during the past ten years.

The application of vanadium in cast steels is analysed on the basis of carbon-vanadium cast steels, nickel-vanadium steels, manganese-vanadium and other vanadium-cast steels. Generally speaking, the main advantage is the increased impact ratio, and the higher impact strength and wear resistance without decreasing ductility in tension. The three types in general use are those of 0·28—0·42% C and 0·15% V min.; 0·31% C, 1·32—1·65% Ni and 0·08% V; and 0·26—0·33% C, 1·40—1·70% Mn and 0·08—0·12% V. These types are largely used for heavy machinery, hydraulic presses, railway equipment, etc.

The importance of vanadium in tool steels is one of the most useful chapters in the book, and it is stated that some 85% of American high-speed tool-steel requirements are met by the usual 18/4/1 composition, although the addition of 2% vanadium instead of 1% increases both cutting capacity and high-temperature stability, and also contributes extra toughness and forgeability. It is suggested that the best method at present available of estimating the cutting capacity of high-speed tool steels is by measurement of indentation hardness at high temperatures, and from the data available 1,290° F. appears to be a suitable temperature, figure of comparison showing that vanadium contributes considerable hot hardness.

The seventh and eighth chapters deal with vanadium-nitriding steels, and vanadium cast irons, respectively. The addition of small quantities of vanadium to all nitriding steels is recommended, even when aluminium is included; all the advantages being claimed, but without the disadvantages, due to the excessive alumina of nitriding steels containing aluminium for a steel containing 0·15% C, 0·45% Mn, 0·25% Si, 2·75% Cr, 0·50% Mo and 0·25% V.

This 190-page book covers a great deal of ground, presenting a large amount of practical information regarding the range of vanadium irons and steels, well indexed for easy reference. It is published by Vanadium Corporation of America, 420, Lexington Avenue, New York, N.Y., U.S.A.

Journal of the Institute of Metals

VOLUME LX (PROCEEDINGS), NO. 1, 1937.

THE sixtieth volume of the Proceedings of the Institute of Metals is larger—by over a hundred pages—than any similar volume issued in recent years, and it contains more plates than any previous issue of the series. This extra amount of matter published by the Institute reflects both the improved position of the non-ferrous metals industry—which has the results of an increased number of researches ready to give to the world—and the strengthened finances of the society that has the task of publishing this new work.

No fewer than 21 pieces of original research are set out in the volume under review. These cover such important subjects as metal spraying, the effect of added elements on aluminium alloys, the resistance of bronze to corrosion-fatigue, the mechanical properties of lead, the rolling properties of zinc, the theory of age-hardening, alloys of magnesium, creep of lead, and dental amalgams. In each case the account of the investigation is followed by a full record of the discussions that took place at the recent London meeting, and afterwards by correspondence. This section of the book concludes with a verbatim report of Professor E. N. da C. Andrade's striking May lecture on "The Flow of Metals," and a record of a special provincial meeting—the first of its kind to be organised by the Institute,—held in Birmingham, to discuss a matter of high local interest, "Directional Properties in Rolled Brass Strip," presented in the form of an illuminating paper by Dr. M. Cook.

Other new features of the Institute's work are dealt with in the annual Report of Council, including the establishment of a £20,000 Endowment Fund, and schemes of co-operation with the Iron and Steel Institute and the American Institute of Mining and Metallurgical Engineers. The latter arrangement constitutes a happy prelude to the first visit of the Institute to the United States, which the Council announces is to be paid in the autumn of 1938, in conjunction with the Iron and Steel Institute.

Altogether the volume contains a vast amount of matter of interest to the engineer and the metallurgist, and reflects the ever-widening field of activities of the organisation that is responsible for the regular appearance of these useful volumes.

Edited by G. SHAW SCOTT, M.Sc., F.C.I.S., London. The Institute of Metals, 36, Victoria Street, Westminster, S.W. 1. £1 11s. 6d.

Business Notes and News

Steel and the Mining Industry

The shortage of steel is having an adverse effect upon the Scottish coal-mining industry, thus affecting the majority of the well-known companies. The point may not be far distant when coal production will be affected, as three-quarters of the Scottish coal is machine cut, this being one of themost highly mechanised sections of the industry.

Metal supports are largely used along the main haulage ways, and steel consumption is around 1,000 tons a week, mostly in the form of special arches, and the local steel-rolling industry is no longer in a position to meet the needs of the mining arch-makers. The lag in deliveries extends over eighteen months, with some orders of two years back still unfulfilled. One reaction is that the standard 4 in. × 3 in. beam sections are scarce, and makers have had to accept heavier sections.

The position is aggravated by the scarcity of sheet bars for the local mills, and mills with the ability to produce mining steel are having to supply sheet bars. It has been suggested that the previous continental sources of supply should be reconsidered in spite of the effect upon existing contracts.

Colvilles, Ltd., are transferring their rolling and fabricating mining steel business to the Lanarkshire Steel Works at Motherwell, and the Glengarnock bending plant will be taken there. The situation is so acute that some of the mining companies have threatened to cut off supplies of coal to Lanarkshire steel works unless sufficient material for the mines is rolled by them.

Foundry Extensions

The considerable extensions which have been made to the foundries of the Incandescent Heat Co., Ltd., Smethwick, have enabled this company to increase their weekly output of grey-iron castings to approximately 50 tons. These castings are of high tensile strength, and range from a few pounds to 4 tons weight. In addition to castings for their own requirements, the company are supplying a large number of castings to the engineering and allied trades.

An interesting development is the production of special heat-resisting metal capable of withstanding temperatures up to 1,100° C., without deformation and with absolute resistance to oxidation and sulphur attack.

More Work for Jarrow

Sir George Gillett, Commissioner for the Special Areas, states that he has decided to acquire a large area of land in Jarrow for industrial development. The area envisaged is that which includes the site of the disused shipyard and steel works on the south bank of the Tyne.

As previously announced, a steel-rolling mill is to be established at Jarrow, and the Town Council has since received an inquiry relating to a proposal to establish a steel-smelting plant in that district. The Council has placed the group of industrialists concerned in touch with the Labour Exchange, railway authorities, public service undertakers, and the Port Authority for any information needed.

Steel Prices to Advance?

Through manufacturers being heavily sold, and with no free tonnage for delivery during the next few months conditions may be said to be quiet in the iron and steel trades,in spite of the continued demand. It is expected thatselling schedules will be revised at the end of the year, advances are anticipated, but to what extent is not yet known.

U.S. Copper Position

An expansion in the output of U.S. refined copper seems likely, but it is difficult to estimate the true position of the U.S. copper market. This is due to the fact that the "apparent consumption" figures of the U.S. Copper Institute represent deliveries rather than the actual volume of metal used by processors and manufacturers, and they may conceal any rise or fall in consumers' stocks. The production figures are more significant, and show that the non-U.S. production of both blister and refined has fallen during the past five months. Analysis gives the following figures:—Non-U.S. blister: May, 120,950; June, 118,230; July, 104,700; August, 107,480. Non-U.S. refined: May, 108,870; June, 113,990; July, 113,660; August, 105,550.

It will be noted that the drop in blister production in July reacted to the detriment of refined production in August, and one can regard the blister figures as more truly representative of the present copper position. No marked rise in production is expected during the next few months, and there have been rumours, of whose authenticity we have no information, of informal agreements among those companies in the restriction scheme to stop increasing output in the majority of cases.

Some Recent Contracts

An order for the complete condensing plant and feed-heating system for the extensions at Battersea power station has been placed with Messrs. Richardson, Westgarth and Co., Ltd., Hartlepool; this including the largest single-sheet condenser yet built in this country.

Orders for a total of 180 bolster truck vehicles have been placed by the L.M.S. Railway with the following companies: The Fairfield Shipbuilding and Engineering Co. (thirty 50-ton bogie bolster trucks); Hurst, Nelson and Co., Ltd., Motherwell (thirty 20-ton double bolster trucks); Metropolitan Cammell Carriage and Wagon Co., Birmingham (sixty 20-ton double bolster trucks); and C. Roberts and Co., Wakefield (sixty 20-ton double bolster trucks).

As part of the £5,000,000 reconstruction scheme which is being carried out at Messrs. Richard Thomas and Co. Ltd., Ebbw Vale steelworks, Messrs. Head, Wrightston and Co. Ltd., of Thornaby-on-Tees, have received a contract valued at approximately £85,000. The plant is for the continuous-strip mill section, and included in the contract are 10 Aetna-Standard automatic tinning machines. In this type of machine the steel-plate which has been previously cleaned in acid baths, is placed in a tank on the entry side of the machines, and is automatically fed through a bath containing molten tin, and delivered to the wet washers and dry cleaners which remove the surplus palm oil, and polish the sheets. On leaving the dry cleaner, the sheets are automatically piled ready for removal by truck. The plant will be complete with special type gas burners, palm oil and soda-ash preparation and circulation systems, and all other auxiliary plant.

It is interesting to note that this part of the order alone involves the building of over 100 machines, and in the dry cleaners and wet washers over 2,000,000 discs of canvas and swansdown will be required. In addition to the above equipment, the order includes the supply of seven oiling machines which cover the steel plates, used for motor-car bodies, with a film of oil before despatch. Further items which are being provided for the manufacture of tinplate and motor-body sheets are two stretcher levellers, one roller leveller, and a sheet doubling line.

All this equipment is being manufactured by Messrs. Head, Wrightson, under license from the Aetna Standard Engineering Co. of Youngstown, Ohio, U.S.A.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£93	0	0
Chinese		82	0	0
Crude		45	0	0

BRASS.

Solid Drawn Tubes	lb.	0	1	0
Brazed Tubes	,,	0	1	2
Rods Drawn	,,	0	0	9¾
Wire	,,	0	0	9
*Extruded Brass Bars	,,	0	0	6

COPPER.

Standard Cash		£45	10	0
Electrolytic		52	0	0
Best Selected		52	5	0
Tough		51	0	0
Sheets		84	0	0
Wire Bars		53	10	0
Ingot Bars		53	10	0
Solid Drawn Tubes	lb.	0	1	1½
Brazed Tubes	,,	0	1	1½

FERRO ALLOYS.

‡Tungsten Metal Powder nominal	lb.	£0	9	4½
‡Ferro Tungsten .. nominal	,,	0	9	3
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2-4% Carbon, scale 12/- per unit	ton	34	15	0
NOMINAL: 4-6% Carbon, scale 8/- per unit	,,	24	5	0
NOMINAL: 6-8% Carbon, scale 7/6 per unit	,,	24	0	0
NOMINAL: 8-10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon, scale 13/- per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit	,,	49	0	0
‡Manganese Metal 97-98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25-50%	,,	0	12	8
§Spiegel, 18-20%	ton	9	15	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	14	10	0
45/50% basis 45%, scale 5/- per unit	,,	12	0	0
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	15	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20-25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	2	6
Scotland	—	2	2	6
Durham	—	1	18	6
Furnace Coke—				
Scotland	—	2	0	0
S. Wales	—	1	17	6
Durham	—	1	17	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£78	0	0
*Commercial Ingots		58	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	1	1
*Cored Bars	,,	0	1	3

MANUFACTURED IRON.

Scotland—			
Crown Bars	£13	10	0
N.E. Coast—			
Rivets	12	15	0
Best Bars	15	15	0
Common Bars	12	10	0
Lancashire—			
Crown Bars	13	10	0
Hoops	14	2	6
Midlands—			
Crown Bars	13	10	0
Marked Bars	15	15	0
Unmarked Bars	—		
Nut and Bolt Bars	11	15	0
Gas Strip	14	2	6
S. Yorks.—			
Best Bars	15	15	0
Hoops	14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	1	1
*Cored Bars	,,	0	1	3
†Strip	,,	0	1	0
†Sheet to 10 W.G.	,,	0	1	0½
†Wire	,,	0	1	2
†Rods	,,	0	1	2½
†Tubes	,,	0	1	5½
†Castings	,,	0	1	3½

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£6	3	0
Foundry No. 1	5	15	6
,, No. 3	5	13	0
N.E. Coast—			
Hæmatite No. 1	6	3	0
Foundry No. 1	5	3	6
,, No. 3	5	1	0
,, No. 4	5	0	0
Silicon Iron	—		
Forge	5	0	0
Midlands—			
N. Staffs. Forge No. 4	5	3	0
,, Foundry No. 3	5	6	0
Northants—			
Foundry No. 1	5	6	6
Forge No. 4	5	0	6
Foundry No. 3	5	3	6
Derbyshire Forge	5	3	0
,, Foundry No. 1	5	9	0
,, Foundry No. 3	5	6	0
West Coast Hæmatite	6	3	0
East ,, ,,	6	3	0

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.	
Per English ton	Kr.185
Billets, single welded, over 0·45 Carbon.	
Per metric ton	Kr.335-385
Per English ton	£17 11 3/£20 3 9
Wire Rods, over 0·45 Carbon.	
Per metric ton	Kr.385-415
Per English ton	£20 3 9/£21 15 0
Rolled Martin Iron, basis price.	
Per metric ton	Kr.335-355
Per English ton	£17 11 3/£18 12 3
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.360
Per English ton	£18 17 6

f.o.b. Gothenburg.

SCRAP METAL.

Copper, Clean	£39	0	0
,, Braziery	36	0	0
,, Wire	—		
Brass	26	0	0
Gun Metal	41	0	0
Zinc	12	0	0
Aluminium Cuttings	71	0	0
Lead	17	0	0
Heavy Steel—			
S. Wales	3	10	0
Scotland	3	6	0
Cleveland	3	7	0
Cast Iron—			
Midlands	3	5	0
S. Wales	3	10	0
Cleveland	4	2	6
Steel Turnings—			
Cleveland	2	12	6
Midlands	2	5	0
Cast Iron Borings—			
Cleveland	—		
Scotland	2	2	6

SPELTER.

G.O.B. Official	—		
Hard	£15	10	0
English	18	17	6
India	16	0	0
Re-melted	16	10	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£11	10	0
North-East Coast	11	10	0
Midlands	11	10	0
Boiler Plates (Land) Scotland	12	0	0
,, ,, (Marine) ,,	—		
,, ,, (Land), N.E.Coast	12	0	0
,, ,, (Marine) ,,	—		
Angles, Scotland	11	0	6
,, North-East Coast	11	0	6
,, Midlands	11	0	6
Joists	11	6	0
Heavy Rails	10	2	6
Fishplates	14	2	6
Light Rails	10	7	6
Sheffield—			
Siemens Acid Billets	11	15	0
Hard Basic .. £6 17 6 to	10	2	6
Medium Basic, £6 12 6 and	10	0	0
Soft Basic	8	15	0
Hoops	11	15	0
Manchester			
Hoops	11	5	0
Scotland, Sheets 24 B.G.	15	15	0

¶ HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	3	10
Finished Bars 18% Tungsten	,,	0	5	0
Extras:				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to ⅛ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ⅜ in.	,,	0	0	3
,, ,, ¼ in. × ¼ in.	,,	0	1	0

TIN.

Standard Cash	£226	10	0
English	226	10	0
Australian	—		
Eastern	226	15	0
Tin Plates I.C. 20 × 14 box	1	5	6

ZINC.

English Sheets	£32	0	0
Rods	27	10	0
Battery Plates	—		
Boiler Plates	—		

LEAD.

Soft Foreign	£18	0	0
English	20	0	0

* McKechnie Brothers, Ltd., Oct. 14. † C. Clifford & Son, Ltd., Oct. 14. ‡ Murex Limited, Oct. 14.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
§ Prices ex warehouse, Oct. 14. ¶ The prices fluctuate with the price of Tungsten.

FILE THIS IN YOUR CABINET

You will then be able to refer to contents of previous issues easily.

METALLURGIA. *Contents.* For OCTOBER, 1937.

ADVERTISERS' ANALYSIS

Acids
Imperial Chemical Industries, Ltd., Imperial Chemical House, London, S.W. 1.

Aluminium
Aluminium Union, Ltd., Bush House, London, W.C.2.
British Aluminium Co., Ltd., King William St., London, E.C.4.
High Duty Alloys, Ltd., Trading Estate, Slough.
Wm. Mills, Ltd., Birmingham.
Northern Aluminium Co., Ltd., Bush House, London, W.C.2
Rudge Littley Ltd., West Bromwich.

Anti-Friction Metals
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Brass and Bronze
Clifford, Chas and Son, Ltd., Birmingham.
John Holroyd, Ltd., Rochdale.
Manganese Bronze & Brass Co. Ltd., Handford works, Ipswich.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Burners
Nu-Way Heating Plants Ltd., Macdonald Street, Birmingham.

Casehardening Compounds
Amalgams Co., Ltd., Attercliffe Rd., Sheffield.
Fordath Engineering Co., Ltd., West Bromwich.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., W.C.1.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.

Castings (Iron)
Rudge Littley Ltd., West Bromwich.
Wallwork, H., and Co., Ltd., Roger St., Manchester

Castings (Non-ferrous)
Magnesium Castings and Products, Ltd., Slough.
Manganese Bronze & Brass Co. Ltd., Handford Works, Ipswich.
William Mills, Limited, Grove Street, Birmingham.
Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.
Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C. 2.
Sterling Metals Ltd., Coventry.

Coke-Oven Plant
Gibbon Bros., Ltd., Albert Road, Middlesbrough.
Woodall Duckham, Vertical Retort & Oven Construction Co., (1920), Ltd.

Crucibles
Morgan Crucible Co. Ltd., Battersea Works, Church St., Battersea, London, S.W. 11.

Electrodes
British Acheson Electrodes, Ltd,, Sheffield.

Extruded Sections
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Extruded Rods and Sections
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Fluxes.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.

Forging Machines
Schiess Detries, A.- G., Düsseldorf.

Forgings
Northern Aluminium Co., Ltd., London.

Foundry Preparations.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham
Imperial Chemical Industries Ltd. Dept. C.6, Imperial Chemical House, London, S.W. 1,
J. W. Jackman & Co., Ltd., Vulcan Works, Blackfriars Road, Manchester.

Furnace Arches
Liptak Furnace Arches Ltd., 59, Palace Street, Victoria Street London, S.W. 1.

Furnaces (Electric)
Birmingham Electric Furnaces, Ltd., Erdington, Birmingham.
Demag Electrostahl, Germany.
Electric Furnace Co., Ltd., 17, Victoria St., London, S.W. 1.
General Electric Co., Ltd., Magnet House, Kingsway, W.C. 2.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., London, W.C. 1.
Integra Co., Ltd., The, 183, Broad Street, Birmingham.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham
Morgan Crucible Co. Ltd., Battersea Works, Church Street. Battersea, London, S.W. 11.
Siemens Schuckert, Ltd., New Bridge Street, London.
Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, North Road, London, N. 7.

Furnaces (Fuel)
British Furnaces Ltd., Chesterfield.
Burdon Furnace Co., 136, West Princes Street, Glasgow.
Cassel Cyanide Co. Ltd., Room 170F2, Imperial Chemical House, London S.W.1.

(Continued on next page).

Furnaces (Fuel)
Dowson and Mason Gas Plant Co., Ltd., Levenshulme, Manchester.
Gibbons Brothers, Ltd., Dudley, Worcestershire.
Incandescent Heat Co., Cornwall Rd., Smethwick, Birmingham.
James Howden & Co. Ltd., 195, Scotland St., Glasgow, Scotland.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.
Ofag Ofenbau, Düsseldorf, Germany.
Priest Furnaces Ltd., Albert Road, Middlesbrough.

Fused Blocks
Imperial Chemical Industries Ltd. Dept. C.6, Imperial Chemical House, London, S.W. 1.

Gas
British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1.

Gears
Wallwork, Henry, and Co., Ltd., Red Bank, Manchester
Shorter Process Co., Ltd., Savile St. East, Sheffield

Gun Metal Ingots and Rods
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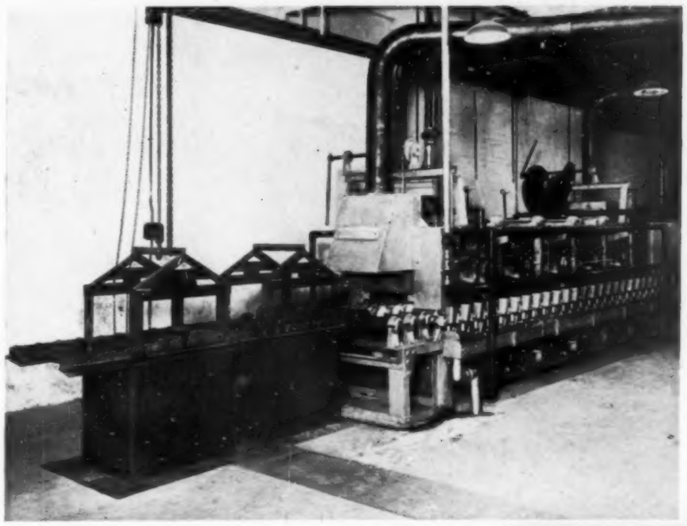

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